157/87

WATER MANAGEMENT

INSTRUCTIONAL-CUM-PRACTICAL MANUAL

Transpiration
Moisture intercepted on leaves and evaporated
Evaporation from soil
CONSUMPTIVE USE =
TRANSPIRATION + EVAPORATION

3720
14.1.87

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WATER MANAGEMENT

Instructional-cum-Practical Manual

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A. K. SACHETI
(Project Co-ordinator)

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद
NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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FOREWORD

The programme of vocationalization of higher secondary education has been accepted by the country as it holds forth great promise for linking education with the productivity and economic development of the country by providing education for better employability of the youth.

In view of the importance of the programme the NCERT is making an all out effort to provide academic support to the implementing agencies in the States. One of the major contributions of NCERT is in the field of curriculum development and in the development of model instructional materials. The materials are developed through workshops in which experts, subject specialists, employers' representatives, curriculum framers and teachers of the vocational course are involved. These materials are then sent for try-out in schools and feedback is collected through questionnaires and through direct contact. The materials are also sent to experts for comment before they are published.

The present manual on **Water Management** has been developed in the manner described above and is meant for the students studying Crop Production and allied vocations. It is being published for wider dissemination amongst students and teachers throughout the country. I hope that they will find the manual useful.

I am grateful to all those who have contributed to the development of this manual. I must acknowledge also the immense interest taken by Prof. A.K. Mishra, Head, Department of Vocationalization of Education in inspiring his colleagues in their endeavours to develop instructional materials. Dr. A.K. Sacheti, Reader, functioned as the Project Coordinator for the development of this title in association with Dr. A.K. Dhote, Lecturer. They have my appreciation and thanks for planning, designing and conducting the workshops, for technical editing and for seeing this manual through the Press.

Suggestions for improvement of this manual will be welcome.

P. L. MALHOTRA
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New Delhi
October, 1985

PREFACE

Ever since the introduction of vocationalization in our school system by several States and Union Territories in our country the paucity of appropriate instructional materials has been felt as one of the major constraints in implementation of the programme and a source of great hardship of pupils offering vocational studies at the higher secondary stage.

The Department of Vocationalization of Education of the National Council of Educational Research and Training, New Delhi has started a modest programme of developing instructional materials of diverse types to fill-up this void in all major areas of vocational education. The task is too gigantic to be completed by any single agency but the model materials being developed by us might provide guidance and impetus to the authors and agencies desiring to contribute in this area. These are based on the national guidelines developed by a Working Group of experts constituted by NCERT.

The present manual is on **Water Management** and is meant for the pupils and the teachers teaching Crop Production and allied Vocations being offered in a number of States. It contains activities (Practical exercises) to be performed by pupils with simple steps to follow, precautions to be taken and data to be obtained and processed. Each activity is complete with objectives, relevant information, behavioural outcomes, evaluation, etc. It is hoped that the users will find them immensely useful.

The experimental edition of the manual was developed by a group of experts as contributors in a workshop held at the Andhra Pradesh Agricultural University (APAU), Rajendranagar, Hyderabad, Andhra Pradesh. The same was later circulated to receive the feedback from the user pupils and teachers in the States of Tamil Nadu, Andhra Pradesh and Maharashtra. After a period of one year for the try-out, the feedback was received and accordingly the experimental edition was suitably reviewed and revised through a committee of experts in a workshop held at the University of Agricultural Sciences, Hebbal, Bangalore. The names of the contributors and reviewers are mentioned elsewhere and their contributions are admirably acknowledged. We are grateful to all the institutions, students and teachers who have used the manual and sent their comments. Our thanks are also due to Shri V. Subbiah retired Agronomist, College of Agriculture,TNAU, Madurai, Tamilnadu for the pains he took in varyfying the authenticity of the contents of the experimental edition of the manual. Dr. A.K. Sacheti, Reader and Co-ordinator of this Project and Dr. A.K. Dhote, Lecturer, Department of Vocationalization of Education deserve special thanks for editing and bringing the manual in the present form. The assistance of all in the APAU, **Rajendranagar**, Hyderabad, Andhra Pradesh; the University of Agricultural Sciences, Hebbal, Bangalore and the Deparment of Vocationalization of Education, NCERT is also thankfully acknowledged.

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The following experts participated in the workshops conducted by the NCERT. Their participation as contributors or reviewers is gratefully acknowledged.

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ABOUT THE MANUAL

Under the programme of Vocationalization of Education about 20 different groups of vocational courses in the area of agriculture have been introduced by nine States and three Union Territories so far. These courses have been running for the last six or seven years. From the very beginning the Department of Vocationalization of Education in the NCERT has been working hand in hand with the State organisations concerned, through various programmes organised for State officials, vocational teachers, and others. In fact, by now the Department has conducted on-the-spot studies of vocational programme in large number of States, to find out merits and demerits of the programme and to suggest appropriate measure to resolve the problems in 'vocational agriculture education'. These programmes have revealed that there was a great dearth of suitable textual/instructional materials; the need for practical manuals, especially, was urgently felt. The development of instructional materials and the imparting of practical training become even more important when one considers the purpose for which the vocationalization of education programme has been launched. The main aim of the programme is to prepare the pupil for purposeful and gainful employment (wage-earning or self-employment).

The Department constituted a Working Group during the year 1982 to formulate guidelines for developing models for a variety of instructional materials.

Based on the guidelines formulated by the Working Group, Crop Production, which is an important and popular vocational course in agriculture, was selected by the Department for the purpose of development of instructional materials in a phased manner. To begin with, the development of instructional-cum-practical manuals has been taken up.

The content of Crop Production and similar courses offered by the States and Union Territories under different titles was thoroughly analysed and it was felt that seven manuals would be necessary to cater to the needs of the course. The present manual on **Water**

Management is one of them. This manual is intended to help both teachers and pupils in the study of water and its management as preparation for this vocation. While developing the manual, care was taken that it should include the maximum number of Activity Units (practical exercises) so that it can fulfil the requirements of the course prescribed by the States and Union Territories in the Crop Production as well as in other vocational courses.

These Activity Units are essential to develop the required vocational skills in the pupils. The manual explains in detail the 'what', 'why', and 'how' of these Units.

In the manual each Activity Unit has been dealt with under several sub-heads, *viz.*, instructional objectives, relevant information, precautions, materials required, procedure, observations, expected behavioural outcomes and questions.

Before commencing the actual work under any Activity Unit, the teacher should know what exactly the pupils have to learn and do, and should also assess whether they will be able to do that. Therefore, in the beginning, instructional objectives for the pupils should be framed in behavioural terms by the teacher.

In order to acquaint the pupils with the Activity Unit the teacher should provide them with the required theoretical knowledge or information relevant to the activity. This will help the pupils to properly understand the Activity Unit. In other words, the 'what' and 'why' parts of the Activity Unit should be explained in advance by the teacher.

Once the pupils have understood the relevant theoretical instructions, the teacher should tell them about the precautions which are to be taken before and during the actual execution of the Activity Unit. This will facilitate smooth working. The 'how' part of the Activity should be explained by the teacher in the 'procedure' which pupil should follow while performing the Activity Unit.

Under the sub-head 'observations', the teacher should tell what to observe and in view of that the pupil should observe the situation, take readings, note down the temperature and similar other points, under each Unit; these may vary from Unit to Unit. Wherever calculations are required to be done to obtain the results, this should also be indicated under this head or under separate head.

At the end of the Activity the pupil will have acquired certain abilities which should be closely related with the instructional objectives formulated for each Activity Unit. These abilities should be listed under the sub-head 'expected behavioural outcomes'.

Evaluation should be based on the abilities acquired and it should be done by the teacher concerned.

For evaluating each aspect, the teacher will use a four-point scale, i.e., A, B, C & D, and for each Activity Unit the Grade Point Average can be calculated as indicated below :

Suppose there are four aspects, each carrying equal weightage, and a pupil obtains 2A's, 1 C and 1 D and if A = 4 point, B=3, C=2 and D=1 point; then, based on the grades, the pupil will get 11 points. When the number of points obtained is divided by the total number of aspects examined, it will give the Grade Point Average, which, in this case, is 2.75. The tabular presentation is as under :

Aspects	*Weightage*	*Grades Obtained*	*TOTAL POINTS (weightage × point-equivalent to grade obtained)*	*Grade Point Average*
1	1	A	1 × 4 = 4	
2	1	C	1 × 2 = 2	= 11/4 = 2.75
3	1	D	1 × 1 = 1	
4	1	A	1 × 4 = 4	
			11	

At the end of the Activity Unit, some questions relevant to it are also given. The pupils should write the appropriate answers after the completion of the Activity Unit and teacher should examine them. If required, he should make suitable corrections and give suggestions. However, answers to these questions will not be considered for the purpose of grading.

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INTRODUCTION

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Water is one of the most important inputs in crop production, as besides being a constituent, it influences almost all the biophysiological processes of plants. It also influences the availability and uptake of plant nutrients from the soil and helps to maintain plant temperature within the desirable limits through transpiration. Hence, its management in crop production assumes great significance. Scientific water management aims at optimal utilization of available water resources in crop production without affecting soil health adversely. Inadequate supply of water causes reduction in crop growth and yields. Whenever soil water becomes inadequate to support normal plant growth, water is applied artificially, which is known as irrigation. Once irrigation is to be applied, the important questions that arise are: (i) when to irrigate, (ii) how much to irrigate and (iii) how best to irrigate.

Attempts have been made in the manual to answer these questions. The estimation of plant available moisture and deficit expressed as depth in the rooting zone enables one to decide "How much to irrigate". The exercise on water measurement helps to apply the desired quantity of water. Determination of water requirement and criteria for scheduling irrigation help to decide "When to irrigate". Selection of a suitable method of irrigation in a given situation will answer the question "How best to irrigate".

The conveyance of water without much loss is very important. The construction and laying out of prefabricated irrigation channel ensures water conveyance from source to the field with minimum losses.

The concept of plant available water capacity enables one to avoid application of excess water which further helps to minimise water-logging, salinity and alkalinity of soil, avoid poor aeration and saves water which can be used for irrigating more area.

In irrigation management, it is highly pertinent to determine quality of water and decide the suitability, as all waters maynot be equally useful for application. It is a common experience in irrigated agriculture that waterlogging and salt accumulation pose serious problems. Hence, irrigated agriculture needs a good drainage system. In order to lay it down, knowledge of water table depth and hydraulic properties of soils are essential. The drainage system provides suitable water and air ratios in root zone and helps to optimise crop production.

Water management is not only important in irrigated agriculture but under rainfed conditions as well. Under rainfed conditions, it chiefly involves moisture conservation and recycling of harvested water. It is needless to say that under semi-arid conditions precipitation has to be conserved as much as possible and use the soil stored water very efficiently for raising crops. Methods for rain water management have been described and exercises have been designed in order to generate interest in the pupil to use this knowledge in crop production. Runoff is inevitable under high rainfall intensity. If this excess water is harvested and used for supplementary irrigation, two crops can be grown where one grew before. This is one of the most important methods to increase the productivity for maximising water productivity under both irrigated and rainfed agriculture.

It is evident from the above description that water management includes various aspects of agricultural sciences such as agronomy, soil science and agricultural engineering. Therefore, it needs to be considered in an integrated manner. An attempt has been made here to give information on water management in an integrated way to the pupils of Crop Production and allied vocations to optimise yield per unit of water.

1. Activity Unit

DETERMINATION OF SOIL MOISTURE CONTENT

1.1 Instructional objectives :

The pupil should be able to :

- — explain the importance of soil moisture determination :
- — determine moisture content in a soil sample;
- — calculate moisture content on dry weight and volume basis;
- — calculate soil moisture in terms of depth.

1.2 Relevant information :

—Importance of soil moisture determination

The determination indicates the amount of moisture present in the soil. This knowledge is essential to decide the time and the quantity of irrigation water to be applied.

— How soil moisture content is expressed ?

Soil moisture content (%) can be expressed on dry weight or volume basis.

Dry weight basis : $\Theta w = Wm / Ws \times 100$
Volume basis : $\Theta w = Vm / Vs \times 100$

Where : Θw = Moisture content on dry weight basis.
Wm = Weight of moisture in soil sample (g),
Ws = Weight of oven dry soil (g),
Θv = Moisture content on volume basis,
Vm = Volume of moisture (cm^3),
Vs = Volume of soil (cm^3).

Moisture content on dry weight basis can be converted into volume basis multiplying it by the bulk density of the soil Db.

$$\Theta v = \Theta w \times Db$$

The bulk density is the dry weight of the soil per unit of its bulk volume and is expressed as grams per cubic centimetre (g cm^{-3}).

— *Methods of soil moisture determination*

In the laboratory soil moisture content in samples can be determined by (a) gravimetric method, (b) rapid moisture meter using calcium carbide, (c) spirit burning method and (d) soil moisture gauge. In the field soil moisture content can also be estimated by using (a) resistance blocks, (b) tensiometers and (c) neutron moisture meter. Of these methods, the gravimetric method is the easiest, most practicable and largely used for the purpose of irrigation.

— *Soil moisture content by gravimetric method*

When a moist soil is heated at 105°C for about 24 hours, only the water which is held within the soil pores is lost. This amount of moisture is of interest for irrigation, water management and other soil management practices. At this temperature, there is not much loss of organic matter by oxidation and of water which is a part of soil particles.

1.3 Precautions :

- Select a representative spot in a particular plot or field for soil sampling.
- Cover the moisture boxes with tight fitting lids immediately after sampling and keep them in moistened gunny bag or in covered wooden or cardboard box. Weigh at the earliest to avoid any moisture loss by evaporation.
- Cover the moisture boxes with their lids immediately after removing from the oven to avoid any moisture absorption.
- Use a tube auger if the soil is very moist, otherwise a screw or other suitable auger for soil sampling.

1.4 Materials required :

i. Aluminium moisture boxes
ii. Auger (screw auger, tube auger or a bucket auger)
iii. Balance (physical)
iv. Weight box
v. Oven
vi. Desiccator (if available)

1.5 Procedure :

- Take weight of empty moisture boxes with their lids.
- Select representative spots in a plot or field.
- Press the auger or core sampler vertically into the soil to a desired depth (eg. 0-15 cm , 15-30 cm, etc.) and collect the soil sample.
- Mix the sample and take about 30 to 50 g into the weighed moisture box and immediately cover with the lid.
- Weigh the moisture box with the soil sample; remove the lid and put it in the oven at 105^0C.
- Let it dry for 24 hours, then remove it from the oven and cover it with the lid immediately.
- Store the box containing the oven dry soil in a desiccator (if available) containing calcium chloride and allow it to cool.
- Weigh the box immediately containing oven dry soil along with the lid.

1.6 Observations :

The pupil should record the weights as follows :

— Weight of empty moisture box + lid = X= .....g
— Weight of box + lid + moist soil = Y= .....g
— Weight of box + lid + oven dry soil = Z= .....g

1.7 Calculations :

The pupil should calculate the percentage moisture on dry weight and volume basis and also convert it to depth of soil moisture.

— Weight of water lost on drying = (Y-Z) = ...g
— Weight of oven dry soil = (Z-X) = ...g
— Per cent moisture by dry weight (Θw)= $(Y-Z) / (Z-X) \times 100$
— Per cent moisture by volume (Θv)= $(Y-Z)/ (Z-X) \times 100 \times Db$
— Depth of soil moisture = $(Y-Z) / (Z-X) \times Db \times d$ (cm)
where : d= depth of soil layer in cm from which the sample has been collected.

1.8 Expected behavioural outcomes:

The pupil will be able to :

— use properly the auger for sample collection;

Grade

— weigh the samples correctly;
— calculate moisture content on dry weight and volume basis;
— calculate depth of moisture present in the soil layers.

The teacher should evaluate the pupil for the above abilities.

1.9 Questions:

i. Why is the determination of soil moisture content important?
ii. Why should the soil sample be dried in an oven at 105^{0}C ?
iii. Why is soil moisture expressed on dry weight basis?
iv. A soil sample has 20 per cent moisture on dry weight basis. Its bulk density is 1.5 g cm^{-3}.What is the moisture content on volume basis? If the sample is collected from 30 cm soil depth, what is the depth of soil moisture?
v. Soil sample was collected with a core sampler of volume 500 cm^3. The weight of moist soil was 880 g, and the weight of oven dry soil was 800 g. Calculate (a) the moisture content by weight, (b) the bulk density of soil, and (c) the moisture content by volume.
vi. A soil sample brought from a field weighing 48 g lost 8 g in weight on oven-drying. Find out the moisture content on volume basis if 100 cm^3 of oven dry soil weighed 140 g.

2. Activity Unit

DETERMINATION OF AVAILABLE SOIL MOISTURE

2.1 Instructional objectives :

The pupil should be able to :

- explain the concept of available soil moisture;
- distinguish the upper and lower limits of available soil moisture;
- interpret the factors influencing available soil moisture;
- determine available soil moisture.

2.2 Relevant information:

— *Forms of soil water*

Based on the force with which water is held in the soil, it can be classified into gravitational, capillary and hygroscopic water.

The gravitational water moves under the force of gravity. The capillary water is held between field capacity and hygroscopic coefficient. A part of this is the available soil water. It is shown in Fig. 2.2.1. The hygroscopic water adsorbed on soil colloids is not available to plants.

— *Definition of soil moisture constants*

—FIELD CAPACITY :

It is the moisture content of a soil on oven-dry basis after free drainage of a saturated soil in the absence of evaporation, which usually takes place in 2-3 days. Sandy soils reach field capacity earlier than clayey soils. At field capacity level, the soil water is drained off the macropores but the micropores are still filled with water. At this level, water is held with a force (tension) ranging from 1/10 to 1/3 atmospheric pressure. The field capacity is the upper limit of available soil moisture for most of the crops except submerged paddy.

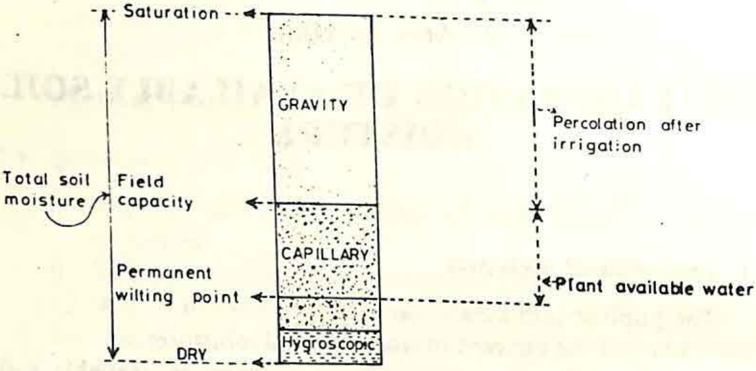

Fig. 2.2.1 SOIL MOISTURE QUANTITIES

—PERMANENT WILTING POINT :

It is the moisture content in percentage of dry weight of the soil, at which nearly all plants wilt and do not recover even when water is added from an outside source. At wilting point, the water is held with a force (tension) of 15 atmosphere pressure. At this stage, though some water is still present in the micropores and around individual soil particles, it is not available for plant use. The wilting point is the lower limit of available water for most of the crops. Water available for plant at this point is considered to be zero.

— *Factors influencing available water*

a. SOIL CHARACTERISTICS:

Important soil characteristics influencing the total available soil moisture are : texture, structure, nature of clay minerals, organic matter content, salt content and soil depth.

In general, fine textured soils contain more water between field capacity and permanent wilting point than coarse textured soils (Appendix-I). In coarse textured soils with their larger proportion of non-capillary pore space, most of the water is released within a narrow range of tension. That is why frequent and light irrigations are necessary for such soils.

The range of available water holding capacity of different types of soils is given in table 2.2.1.

Table 2.2.1. Range of available water holding capacity of soils on dry weight basis.

Soil texture	*Field capacity (%)*	*Permanent wilting point*	*Available moisture (%)*
Sand	6—12	2—6	4—6 .
Sandy loam	10—18	4—8	6—10
Loam	18—26	8—12	10—14
Silt loam	23—31	11—15	12—16
Clay loam	27—35	13—17	14—18
Clay	31—39	15—19	16—20

Reproduced from Sankara Reddi, G.H., Management of Irrigation Water. TECH. Bull. No. 3, APAU, 1976.

b. PLANT CHARACTERISTICS:

Important plant characteristics influencing the use of available water are—rooting habits, drought tolerance, stage and rate of growth.

c. WEATHER PARAMETERS:

The important weather parameters such as temperature, relative humidity, wind velocity and sunshine duration which determine the evaporative demand of the atmosphere also influence the use of plant available water.

— *Determination of available water*

In the determination of available soil moisture, two important steps are involved : (a) determination of the field capacity, and (b) determination of permanent wilting point.

2a. Sub Unit : **Determination of Field Capacity**

2a.1 Relevant information :

Field capacity can be determined by using pressure plate apparatus in the laboratory. But the most practicable and easy method is the field method.

2a.2 Precautions :

— Select a representative site in the field.

- Take adequate care in prevention of evaporation from the experimental site.
- Weigh soil sample carefully.
- Ensure that water table is not within two metres from the soil surface.

2a.3 Materials required :

i. Straw mulch and black polyethylene sheet
ii. Spade
iii. Required quantity of water
iv. Screw auger or tube auger
v. Moisture boxes
vi. Physical balance with weight box
vii. Drying oven
viii. Graph paper

2a.4 Procedure :

- Select a representative spot in the field.
- Bund an area of 2m × 2m on all the four sides, clean and level it (Fig. 2a.4.1).

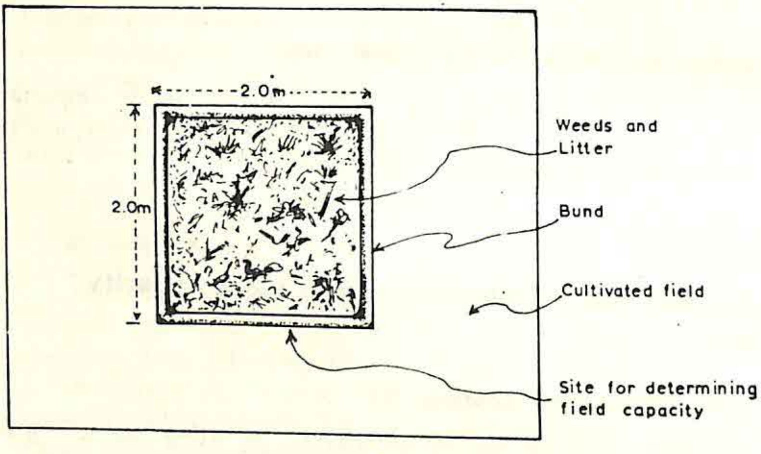

Fig. 2a.4.1 SITE WITH BUND

- Apply sufficient water to the plot so that the soil profile to a desired depth gets saturated (Fig. 2a.4.2).

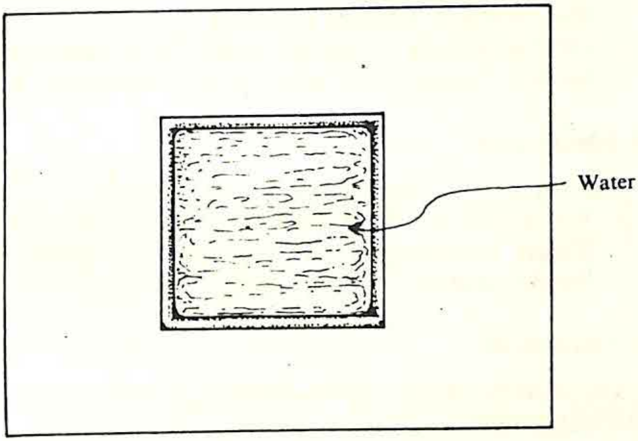

Fig. 2a.4.2 CLEAN SITE FILLED WITH WATER

- To prevent evaporation from the experimental plot after disappearance of the ponded water, cover it with a black polyethylene sheet and spread straw mulch over it. If polyethylene sheet is not available, use gunny bag cover in its place.
- Take soil samples at different time intervals (12-24 hours) from the desired depth with an auger (Fig. 2a. 4.3) and

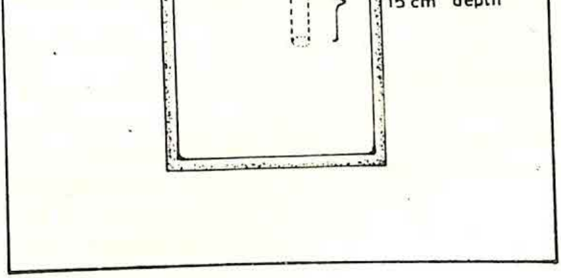

Fig. 2a.4.3 SOIL SAMPLING WITH TUBE AUGER

determine the soil moisture content till the values of two successive samples are nearly equal. After each sampling, the plot should be covered as before.

- Plot the readings on a graph paper. The lowest reading can be taken to represent the value of field capacity of the soil.

2a.5 Observations :

The pupil should record the following weights :

- Weight of moisture box with moist soil = W_1 = ... g
- Weight of moisture box with soil after oven drying = W_2 = ... g
- Weight of empty moisture box = W_3 = ... g

2a.6 Calculations :

The pupil should calculate the field capacity (% dry weight basis) by the following expression :

Field capacity (FC) = $W_1 - W_2 \,/\, W_2 - W_3 \times 100$

2a.7 Expected behavioural outcomes :

The pupil will be able to :

- appreciate the importance of proper selection of the experimental site;
- explain the need for completely wetting the surface layer;
- determine the field capacity of the soil;
- predict the time taken by a particular soil to reach the field capacity;
- explain why the field capacity of different soil types varies.

Grade

The teacher should evaluate the pupil for the above abilities.

2b. Sub Unit : **Determination of Permanent Wilting Point (By Sunflower Method)**

2b.1 Relevant information :

Wilting point of soil in laboratory can be determined by using pressure membrane apparatus or by sunflower method, if the former is not available.

2b.2 Precautions :

— Use seeds of a dwarf variety of sunflower.
— Use atleast five replications for this determination.
— Select plants bearing three pairs of leaves.

2b.3 Materials required :

i. Five 600 g capacity cans with lids having 4 holes.
ii. Sunflower seeds
iii. Glass tube (5 cm x 0.5 cm diameter)
iv. Sealing wax
v. Moisture cans and soil auger
vi. Physical balance with weight box
vii. Drying oven
viii. Bell jars, if available, or a wire cabin of 25 cm x 25 cm 50 cm with polyethylene cover
ix. Water trays
x. Soil samples
xi. Saw dust

2b.4 Procedure :

— Take 5 cans for the experiment each with a drain hole at the bottom.
— Fill the cans with 500 g of air dry soil with gentle tapping; add enough water to bring it near saturation and allow it to drain till the surface soil is fit for sowing.
— Sow 4 seeds of sunflower in each can and allow them to germinate.
— After emergence, thin the plants to two per can and allow

them to pass through two holes in the lid of the can.

- Place the cans under insulation by keeping them in moist saw dust in order to avoid heating of the cans.
- Grow the sunflower plants till they develop 3 pairs of leaves.
- Water the plants as and when needed.
- Insert a glass tube to the middle of the soil column for aeration and plug the top with cotton wool.
- Water the plants for the last time. Seal the soil surface and close the drainage hole with wax. Then allow the plants to wilt.
- As soon as the plants show loss or turgor, transfer them to a dark humid chamber (Fig.2b.4.1). The cans with plants can be kept ir a small water tray and covered with a bell jar or a wire cabin to create high humidity condition. The whole chamber may also be covered with a black polyethylene sheet. The aim here is to close stomata and reduce transpiration.

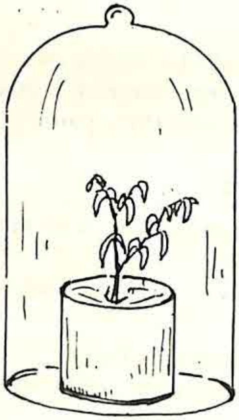

Fig. 2b.4.1 WILTED SUNFLOWER PLANT UNDER HUMID CHAMBER

- Leave the plants overnight to gain favourable water balance by allowing them to extract moisture from the soil. If they gain turgidity, expose them to the atmosphere for a couple of hours and transfer them back to the humid chamber for an overnight.
- Repeat the process till the plants do not recover in the dark humid chamber.
- At this stage, remove the lid and cut the plants. Take duplicate soil samples and composite them. Remove the

roots. Determine the moisture content of the soil which will represent the wilting point of the soil.

2b.5 Observations :

The pupil should record the following weights for each composite sample :

- Weight of moisture box with moist soil (at wilting of the plants) $= W_1 =$ ....g
- Weight of moisture box with soil after oven drying $= W_2 =$ ....g
- Weight of empty moisture box $= W_3 =$ ....g

2b.6 Calculations :

The pupils should calculate the moisture content by the following expression for each composite sample and the average of the five samples will give the permanent wilting point (PWP).

— Moisture content (per cent by weight) at wilting (PWP)

$$= W_1 - W_2 \,/\, W_2 - W_3 \times 100$$

2b.7 Expected behavioural outcomes :

The pupil will be able to:

- determine permanent wilting point of a soil;
- identify the stage of permanent wilting.

Grade

The teacher should evaluate the pupil for the above abilities.

2.3 Calculation of available soil moisture:

The pupil should take the values of FC and PWP from the Sub-Unit 2a and 2b respectively and calculate the available soil moisture as under:

Available soil moisture=Field capacity (FC) – Wilting point (PWP)

Available soil moisture
in the profile (cm) = FC—PWP/100 × d × Db

Where: FC and PWP are in percentage,
d = depth of soil (cm),
Db = bulk density of soil i.e. 1.5 $g\,cm^{-3}$ or any other determined value.

Illustration :

A soil has a moisture content of 30.0 per cent at field capacity and 12.0 per cent at permanent wilting point on dry wright basis. The bulk density of the soil is 1.5 g cm^{-3}. Find out the available water holding capcity per metre depth of the profile.

Soil bulk density = 1.5 g cm^{-3}
Field capacity = 30.0 %
Permanent wilting point = 12.0%
Depth of soil = 1 metre = 100 cm
Therefore, available soil moisture in cm per metre $= 30 - 12/100 \times 1.5 \times 100$
$= 18 \times 1.5$
$= 27$ cm

2.4. Expected behavioural outcomes :

The pupil will be able to:

- — explain what is available water;
- — calculate available water holding capacity of soil.

Grade

The teacher should evaluate the pupil for the above abilities.

2.5 Questions :

i. What is the upper limit of available soil water?
ii. What is the lower limit of available soil water?
iii. The available soil moisture varies from soil to soil, Why?
iv. Why are repeated estimations of soil moisture content necessary for the determination of field capctiy and permanent wilting point?
v. Why is sunflower chosen as the indicator plant for the estimation of permanent wilting point?
vi. Why is watering of the plants stopped after they bear 3 pairs of leaves.?
vii. Why are plants left overnight in darkness?
viii. What is indicated when the plants do not recover in the dark chamber?

3. Activity Unit

DETERMINATION OF PROFILE MOISTURE AND DEFICIT

3.1 Instructional objectives :

The pupil should be able to:

- explain the soil moisture deficit;
- estimate the moisture deficit in soil profile at a particular point of time;
- estimate the quantity of water required to bring back the soil moisture to the field capacity;
- recall that this deficit in soil moisture determines the depth of irrigation.

3.2 Relevant information :

— *What is soil moisture deficit?*

Every soil has an upper limit of its moisture retention, known as field capacity. This moisture in the soil is, however, not retained for long because the moisture from the soil profile is being lost continuously through evaporation from the soil surface and by transpiration through the plants. This loss of moisture from the soil in due course of time leads to the development of a state of moisture deficit in the root zone. The loss can be measured at any time by estimating the moisture status in the root zone and subtracting it from the moisture retained by the soil at the field capacity.

— *Importance of moisture deficit studies*

An estimate of the loss of moisture at any time gives an idea of:

- the soil moisture status in the root zone,
- the content of deficit from field capacity and
- the quantity of water required to bring the soil back to the field capacity.

— *Expression of soil moisture deficit*

The values of field capacity and bulk density are determined layer-wise of a soil profile. To work out the moisture deficit for each soil layer, the following formula is used:

$$Di = FCi\text{-}Wi/100 \times Dbi \times di$$

$$D = \sum_{i}^{n} Di$$

Where : Di = the estimated moisture deficit (cm) in the i_{th} layer,
D = the total moisture deficit in the profile,
di = the depth of the i_{th} layer of soil (cm),
FCi = the per cent moisutre content on dry weight basis at field capacity of soil of the i_{th} layer,
Wi = the per cent actual moisture content on dry weight basis in the i_{th} layer,
Dbi = the bulk density of the i_{th} layer (gcm^{-3}),
$\sum_{i}^{n}$ = summation from 1 to n_{th} layer.

3.3 Precautions :

- Select the spots well inside the field, away from the borders representing the field conditions.
- Draw the samples from the centre of two rows.

3.4 Materials required :

i. Auger
ii. Plastic sheet
iii. Soil moisture boxes
iv. Physical balance with weight box
v. Hot air oven

3.5 Procedure:

- Select 5-6 representative spots in the field.
- Draw soil samples layerwise and estimate the present moisture.
- Calculate the moisture deficit (Di) as per formula given.

3.6 Observations

The pupil should record the following observations:

Field No. Crop Variety Date

Spot No.	*Soil depth (cm)**	*Depth of soil layer (di,cm)*	*Initial wt. of soil + box* (W_1,g)	*Final wt. of soil + box* (W_2,g)	*Wt. of empty box* (W_3,g)	*Wt. of oven dry soil* (W_s,g) $W_s = W_2 - W_3$	*Wt. of water in soil* (W_w,g) $W_w = W_1 - W_2$	*Percent water in soil* $(W_i\%)$ $\frac{W_w}{W_s} \times 100$	*Bulk density* $(g\ cm^{-3})$ Db	*Field capacity (%)* FC	*Deficit (Di, cm)* $D_i = \frac{FC_i - W_i}{100} \times Db_i \times d_i$
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
i.	0-15	15									
	15-30	15									
	30-60	30									
	60-90	30									
	90-120	30									
	120-150	30									
	Total	150									

*Depth of soil sampling will depend upon rooting depth of the crop.

3.7 Calculations :

The pupil should calculate the following:

(a) The average total soil moisture deficit in the root zone as per formula given below:

$$\text{Average total soil moisture deficit in the root zone of the field (cm)} = \frac{\text{Total moisture deficit (cm) of all spots}}{\text{No. of spots.}}$$

(b) $$\text{The irrigation requirement (cm)} = \text{Average total soil moisture deficit} \times \frac{100}{\text{Irrigation efficiency}}$$

3.8 Expected behavioural outcomes :

The pupil will be able to :

- explain the meaning of moisture deficit;
- select sampling spots representing the field for moisture deficit estimation;
- prepare observation sheet;
- compute the moisture deficit to determine the depth of irrigation.

Grade

The teacher should evaluate the pupil for the above abilities.

3.9 Questions :

i. What is soil moisture deficit?

ii. What is the purpose of computation of soil moisture deficit?

iii. Why should you draw samples from more than one spot in the field?

iv. a) Work out the soil moisture deficit in the root zone (0-150 cm) from the data given below :

  b) Work out the extent of moisture contribution from the top 60 cm layer

Soil layer (cm)	*FC (%)*	*Db (g cm^{-3})*	*Wi (%)*
0-7.5	21.3	1.45	11.5
7.5-15	20.9	1.45	13.9
15-30	18.8	1.46	14.3
30-60	18.3	1.52	15.2
60-90	17.9	1.40	15.7
90-150	16.3	1.50	15.7

v. Find out the profile moisture from given data when the soil has an average field capacity value of 28.7% and bulk density 1.5 g cm^{-3}

Profile depth (cm)	*Wt of soil at sampling (g)*	*Wt. of soil after drying (g)*
60 cm	185.6	160.6

Work out the moisture deficit per metre depth of soil.

vi. Work out the depth of irrigation water required if the moisture deficit in 150 cm root zone is 6.0 cm and irrigation application efficiency is 75%.

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4. Activity Unit

LAND SHAPING FOR IRRIGATION

4.1 Instructional objectives :

The pupil should be able to:

- —recall the meaning of land shaping;
- —realize the necessity of land shaping for irrigation;
- —recognize land shaping requirement by visual observation;
- —explain how land shaping is done;
- —do land shaping.

4.2 Relevant information :

— *Land shaping operation*

Due to ploughing and other normal cultivation operations,the smoothness of a levelled or graded land is disturbed. Localised high and low patches are developed. The field operation done to restore these irregularities is called land shaping operation. In contrast to land lavelling and land grading operations, the earth movement is minimal in land shaping. This operation can be done on small area whereas land levelling and grading operations are usually done over larger areas; Land shaping of large areas is done by machines.

— *Necessity of land shaping*

When irrigation water is released in the field, it moves forward as well as downward. If the field does not have proper smooth shape and has high and low patches, the forward movement of water is restricted. More water is accumulated in lower patches and water may not reach the higher patches. This non-uniformity in the spread of surface water also causes a non-uniformity in the wetting of the soil profile. As a result, the crop growth becomes non-uniform and a poor irrigation distribution efficiency is obtained. This is true in the case of rain water management as well. To ameliorate these, land shaping becomes necessary.

— Land shaping requirement

Land shaping requirements can be seen in cropped area by identifying the patches of bad crop growth. If other agricultural inputs are same for the entire field the patches of bad crop growth usually indicate the existance of high or low spots. On a bare land, the best method of identifying the high and low spots are by releasing water in the area. Alternatively, after a rainfall, the area which is dried up quickest is the highest spot and the area which dries up at the last is the lowest spot. If these high and low spots occur randomly in an area, this indicates that land shaping is required.

— Method of land shaping

Land shaping is usually done by simple equipment as buck scraper, float wooden plank etc. which are animal drawn or manually by using spade. Manual land shaping is done when the work is of very small magnitude. Buck scraper can perform a small quantity of earth moving work. A skilled worker and well trained animals can do a good job of land shaping with this. Float and wooden plank usually do a very minor job of land shaping and mostly these do land smoothening work. In using a buck scraper for land shaping work, first the high and low patches are identified on the field. The buck scraper is then run, cutting earth from the high patches and filling this in low patches. Pushing earth to long distances is not possible. Therefore, the earth removed from a high patch is deposited on the nearest low patch. This operation is continued till the desired finish is obtained. If float and plank are to be used, these are run several times over the area to be smoothened. In doing this, minor quantities of earth from high patches are hauled (transported) by these equipment and deposited over the low patched.

4.3 Precautions :

— Check all the joints of a buck scraper.

— Check whether the lower edge of the scraper is uniform.

4.4 Materials required :

i. Buck scraper
ii. Bullock
iii. Operator
iv. Plough and/or harrow

4.5 Procedure :

- Loosen the land by using plough and/or harrow.
- Identify and mark the high and low patches.
- Operate the buck scraper carefully so that the earth from high patches is removed and is uniformly deposited over the low patches.
- Repeat this operation several times, each time cutting a small quantity of earth, till the desired finish is obtained.

4.6 Observations :

The pupil should note the following :

- Whether the earth is being removed from high patches?
- Whether the earth is being deposited uniformly over the patches?
- Whether the required smoothness has been achieved?

4.7 Expected behavioural outcomes :

The pupil will be able to:

- explain what is land shaping;
- judge from visual observations on cropped or bare land where land shaping is required;
- suggest land shaping equipment to use under a given situation;
- do or supervise land shaping operation.

Grade

The teacher should evaluate the pupil for the above abilities.

4.8 Questions :

i. What do you mean by land shaping?
ii. Why is land shaping necessary for irrigation?
iii. What are the different equipment used for land shaping?
iv. How will you find whether a piece of land requires land shaping operation?

5. Activity Unit

METHODS OF IRRIGATION

5.1 Instructional objectives :

The pupil should be able to:

- distinguish the different methods of irrigation;
- explain the utility of each method;
- lay out most common methods of irrigation.

5.2 Relevant information :

Irrigation methods refer to the methods of application of water to the cultivated land. There are four such methods, namely;

i) Surface irrigation :

In this method water is released in the field from adjacent irrigation channels. Depending on the features of land preparation, the surface methods are classified into border, basin (ring and check), corrugation and furrow methods of irrigation.

ii) Subirrigation :

In this method, water is conveyed in channels running close to the plant roots and water seeps from the sides of the channels towards the plant roots.

iii) Sprinkler irrigation :

In this method, water is conveyed through pipelines under high pressure and sprayed over the crops through nozzles. The spray of water somewhat resembles the rainfall.

iv) Drip irrigation :

Water is conveyed through pipelines at relatively lower pressure than in sprinkler and is released very near the plant stem, just at the soil surface or little below the soil surface by an emitter at a very slow rate.

The basin and furrow methods of irrigation are most common in the country. In the case of large farms, border method of irrigation is also suitable. Subirrigation is rather wasteful of water. Sprinkler and drip are suitable for water scarcity areas and can be used under varying conditions of soil texture, land slope and type of crop. These two methods are, however, not very common in the country. Both of these needs elaborate layout of pipelines which may have to be shifted from one place to another for more coverage of area under irrigation. These are nevertheless very scientific methods of irrigation in which desired control on water delivery can be achieved. Usually most surface methods of irrigation are wasteful in water application. However, these are easy to adopt, traditionally followed by our farmers, adaptable under canal as well as tubewell irrigation and necessary for high water requiring crops such as paddy. With proper field preparation, appropriate selection of stream size, slope, etc., it is possible even in surface methods to achieve high efficiency of water application. The recommended range of values of the above parameters are incorporated in the Activity Unit 7 on irrigation efficiencies.

— *Border irrigation*

In this method, the field to be irrigated by one channel is divided into parallel strips. This is suitable for all close growing crops such as wheat, bajra, berseem and is adopted in topography with 0.05 to 0.5% slope. Both light and heavy soils can be irrigated by this by proper selection of border length, stream size and slope. A particular requirement in border irrigation is that the longitudinal slope must be uniform and the transverse slope must be zero or negligible. Irrigation water is released at the upstream end of the border from the irrigation channel.

— *Basin irrigation*

There are two sub groups in this, namely, ring basin and check basin. Ring basin method is suitable for sparcely growing orchard crops. In this method a circular bund is constructed around the plant to create a basin for irrigation water application. These basins are suitably connected to irrigation conveyance channels. In check basin or commonly known as basin method, the field is usually divided into rectangular plots separated by small bunds. Rice fields are good examples of this method. Some other close growing crops (e.g. wheat) and vegetables are also irrigated by this method. This is suitable for lands of flat topography.

– *Furrow irrigation*

In this method, the flat field surface is converted into a series of ridges and furrows. This method is suitable for crops which are cultivated under ridge-furrow method of cultivation, such as sugarcane, potato, groundnut, etc. Among the various surface methods, there is a relative saving of water in this method and in case of limited water, alternate furrows may be irrigated without much adverse effect on the yield. A special method of furrow irrigation is called corrugation irrigation. In this method, small ridges and furrows are made which are sometimes very close to each other. This is used for irrigating close growing crops which do not require interculture such as small grains and may also be used in conjunction with border irrigation.

5a. Sub Unit : **Laying out Check Basin for Irrigation**

5a.1 Precautions:

— Ensure proper levelling of the plots.
— Fix the plot size taking into consideration the soil type, the field slope and stream size.

5a.2 Materials required :

i. Spade
ii. Measuring tape
iii. Rope for aligning bunds
iv. *Jandra* (Land leveller)

5a.3 Procedure :

— Select properly levelled field.
— Form check basins (rectangular plots) of the required size with proper bunding on all sides, keep bund size depending on the depth of water to be applied (Fig. 5a.3.1).
— Calculate the irrigation time necessary to give the desired quantity of water based on stream size.
— Lay out the irrigation channels on the upper side of the field.

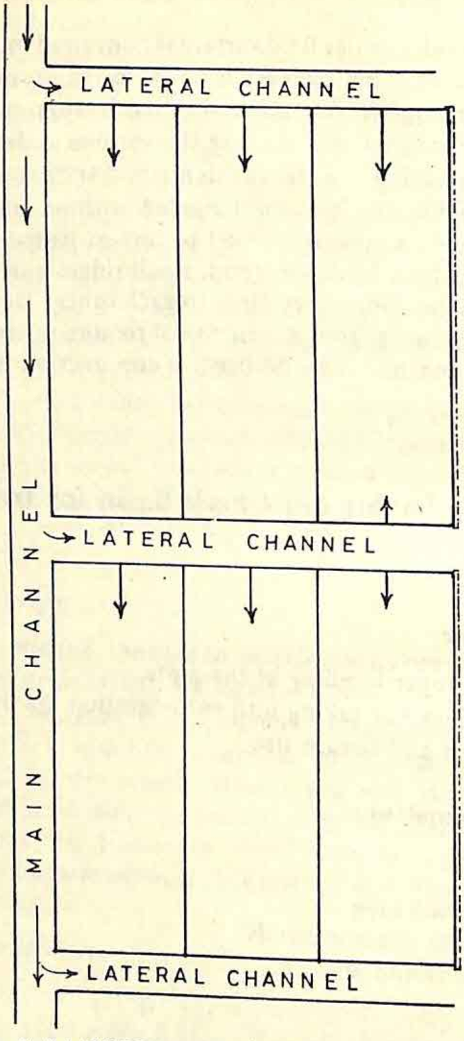

Fig. 5a.3.1 CHECK BASIN METHOD OF IRRIGATION

- Irrigate the plot for the calculated duration or till the desired amount of water has been applied.
- Go to the next plot.

5a.4 Observations :

The pupil should observe the following:

- Whether water is spreading uniformly in the check basin?

- Whether the bunds of the check basin are intact?
- Whether desired quantity of water has flown into the check basin?

5b. Sub Unit : **Laying Furrow Irrigation System**

5b.1 Precautions :

- Ensure proper length of the furrow in relation to land slope and stream size.
- Ensure proper size and spacing of furrow as per needs of the crops.
- Never let the water over flow the ridge top.

5b.2 Materials required :

i. Measuring tape
ii. Pegs and markers
iii. Rope for aligning the ridges and furrows
iv. Ridge plough
v. Spade

5b.3 Procedure :

- Level the field first for laying out the furrows.
- Using the ridge plough or spade, lay out the furrows as per the spacing required.
- Make irrigation channels at the head of the field at right angles to the length of the furrows.
- Run the water into the channels and then into the furrows.
- Irrigate furrows for the required duration to give the desired depth of water (Fig. 5b.3.1).

5b.4 Observations :

The pupil should observe the following :

- Whether the water is flowing uninterruptedly along the furrow?
- Whether there is any breaches along the furrow?
- Whether there is any outflow at the furrow end?

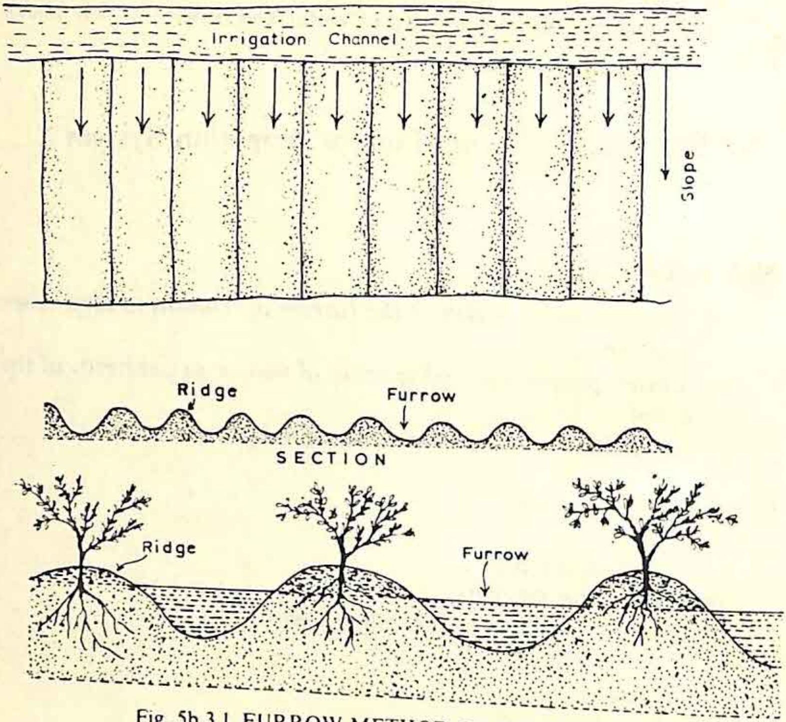

Fig. 5b.3.1 FURROW METHOD OF IRRIGATION

5.3 Expected behavioural outcomes :

The pupil will be able to :

- explain the different methods of irrigation;
- compare surface methods of irrigation;
- suggest a proper method of surface irrigation;
- layout a check basin system in the field;
- layout a field into ridges and furrows;
- judge that there is water saving under furrow irrigation.

Grade

The teacher should evaluate the pupil for the above abilities.

5.4 Questions :

i. What are the different surface methods of water application?

ii. Under what situations are drip and sprinkler methods of irrigation used?
iii. Which crops are suitable to be irrigated by (a) basin method (b) furrow and (c) border method?
iv. In which surface method of irrigation, there is more saving of water?
v.a. The size of a check basin should be large with a small size stream (True/False)
  b. The check basin size in a sandy soil should normally be smaller than in heavy clay soil (True/False).
  c. The furrow method of irrigation can be safely used for paddy crop (True/False).
  d. The furrow method of irrigation is more suited in clayey soils than in sandy soils (True/False).

6. Activity Unit

MEASUREMENT OF IRRIGATION WATER

6.1 Instructional objectives :

The pupil should be able to :

- — explain the methods of water measurement;
- — select method to be adopted under a given situation;
- — measure irrigation water by a few common methods;
- — calculate the time required for one irrigation by using a measuring device.

6.2 Relevant information :

— Necessity for on-farm water measurement

For proper growth, the plants need a certain quantity of water at a given time interval. In conveying water from the source, considerable part is lost through seepage. The breeches in-between may cause further uncertainty on the quantity of water flowing in the channel. Therefore, to know the quantity of water flowing in the channel, to give right quantity of water in the field, to run a pumping system or an outlet for the correct time to satisfy the irrigation needs, on-farm water measurement is necessary.

—Methods of water measurement

Irrigation water may have to be measured in large canals carrying discharges of several thousand litres per second, in small water courses carrying discharges of 30-36 litres per second and also for individual plots requiring discharges of 5-10 lit/sec. Measurement of irrigation water may also be required when the water is being conveyed through pipelines as may be in the case of irrigation from ground water source. The technique of measurement, therefore, varies. In general, the basic measurement can be of either the volume of water flow over a given time or directly of the rate of flow. The common types of flow measurement devices are the current meter, float, flumes, gauges, flow meters, venturimeters, orifice meters calibrated scale (for pipe flow having free over fall, also called coordinate method of measurement), weirs and notches. Of all these, the current meter and the float actually measure the velocity of water flow and needs to be multiplied by the area of flow to obtain the discharge or the flow rate. Using a bucket of known volume and watch to record the time required to fill the bucket is also used to measure the volume of water flow over a certain time.

— *Flow measurement in open channels*

i) USE OF STAFF GAUGE :

For large size conveyance channels which are lined such that the channel shape is not likely to change with time, the staff gauge, made of wood or metal, may be used. A staff gauge is a graduated scale which gives the depth of flow or it can also be calibrated to give the discharge directly. The staff gauge is usually installed in the conveyance channel at the upstream of a structure or below a culvert etc. For rough estimate of the flow rate this method is suitable. Precise estimate of discharge is not possible because the water surface fluctuates due to wave formation. If a calibrated staff gauge is installed in a channel of permanent cross section, its reading directly gives the discharge flowing through the channel.

ii) USE OF CURRENT METER :

Current meter, consists of freely moving propeller rotating around a horizontal axis or a set of conical cups rotating around a vertical axis. The number of rotations per minute is made countable through a battery operated counter. When the current meter is lowered into the flowing body of water the propeller or the cups rotate. The number of rotation is calibrated against the velocity of water which can be read in the chart available with the current meter.

It gives the velocity of water at the point where it is lowered. For calculation of the flow rate, it is necessary to know the mean velocity of flow. To estimate the mean velocity, the channel cross section is divided into a number of sections. The current meter cups/propeller is lowered at the centre of each section at a depth of 0.6 time the depth of flow from the surface and the velocity is estimated from the recorded number of revolutions per minute. Alternatively, the velocity is determined at 0.2 and 0.8 time the depth and the average of the two is computed to obtain the mean velocity. The mean velocity of a segment is multiplied by the area of the segment to get the discharge passing through the segment. This procedure is repeated for all the sections and the discharge obtained for each section is added to the total discharge.

iii) USE OF FLUMES :

Flumes are structures constructed or fabricated to create a certain flow condition when the water flows through these. For each type of flume, a definite relation exists between the depth of flow in the flume at a particular section and the discharge. The flumes can be built of masonry or concrete *in situ* or these can be portable made of metal sheets. The most common type of flume is called the Parshall flume (Fig. 6.2.1). Metal Parshall flumes of different sizes are

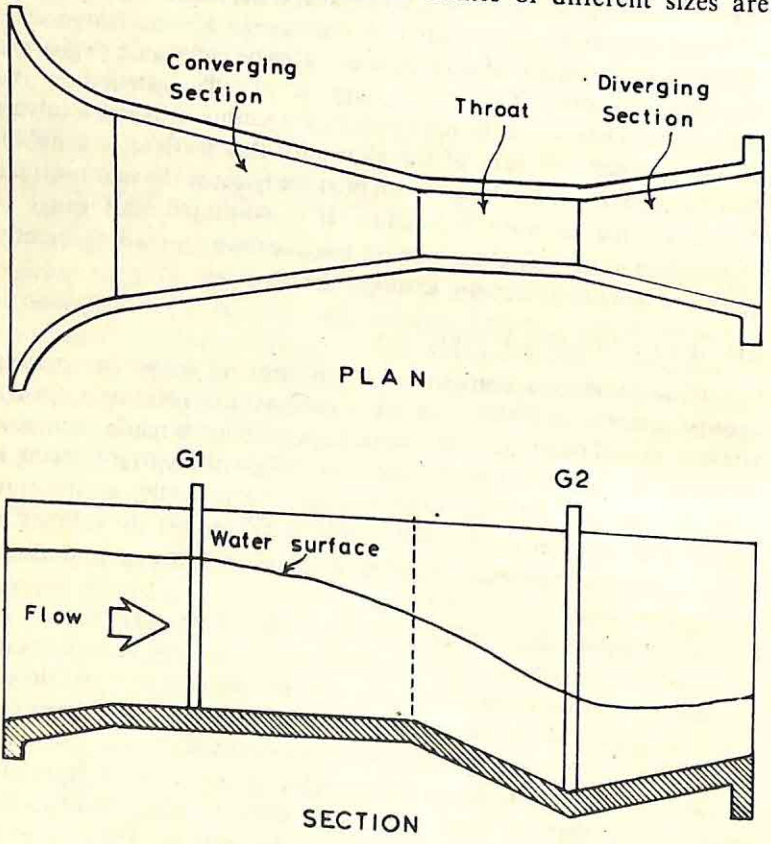

Fig. 6.2.1 PARSHALL FLUME

available in the market. Parshall flume sizes are indicated by the width of the throat of the flume. If there is a likely chance of over flowing of the channel banks due to installation of the flume, it cannot be used.

iv) USES OF WEIRS AND NOTCHES :

A regular geometric section such as an inverted triangle (i.e. a 'V'), a rectangle, a trapezium, a circle, etc. obtained by cutting from a metal sheet is used as weir or notch. The various geometric sections have definite relations between the depth of water flowing over these and corresponding discharge. The ideal location to install these are the places in the conveyance channels where a fall exists as these flow measuring devices work when there is a free overfall of water over there. Usually these are used for measuring small discharges as may be obtained in a water course of the discharge from a tube well. The most common type of weir is a 90^0 'V'-notch in which the discharge is calculated by $Q=0.013\ h^{5/2}$ where Q is discharge in litre/sec, h is the height of flow over the notch in cm measured about 4 times h behind the weir.

For relatively large discharges rectangular weirs may be used (Fig.6.2.2). Rectangular weirs are called "contracted" if the lengh of

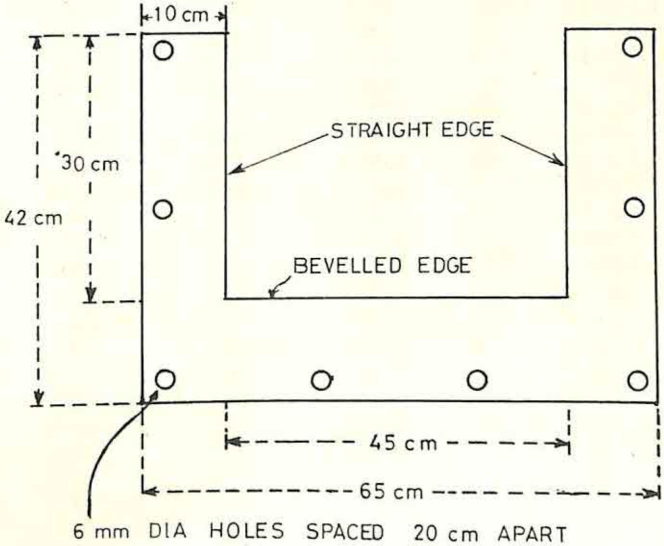

Fig. 6.2.2 DETAILS OF A RECTANGULAR WEIR

crest of the weir is less than the width of the approach channel, and it is called 'suppressed' if the length of the crest of the weir is equal to the width of the approach channel. The discharge formula for the contracted and suppressed rectangular weir are given below:

Contracted rectangular weir

$Q = 0.0184\ (L - 0.2\ h)\ h^{3/2}$

Suppressed rectangular weir

$Q = 0.0184\ L\ h^{3/2}$

Where : Q = discharge (lit./sec)
L = length of crest (cm)
h = head over the weir (cm), measured at a point about 4h behind the weir crest.

Contracted rectangular weir, 90^0 V notch and Parshall flumes are commonly used for flow measurement in small irrigation channels. Tables 6.2.1., 6.2.2. and 6.2.3. give the discharges for these weirs and flumes for different sizes and different heads of water.

Table 6.2.1 : Discharge through contracted rectangular weirs (lit/sec)

Head over weir	*Width of weir*			
cm	*30 cm*	*40 cm*	*50 cm*	*60 cm*
5.0	5.97	8.0	10.1	12.2
5.5	6.9	9.3	11.6	14.0
6.0	7.8	10.5	13.1	15.9
6.5	8.4	11.8	14.9	17.9
7.0	9.7	13.2	16.6	20.0
7.5	10.7	14.5	18.3	22.1
8.0	11.8	16.0	20.1	24.3
8.5	12.9	17.6	22.1	26.7
9.0	14.0	19.0	24.0	28.9
9.5	15.2	20.7	26.0	31.2
10.0	16.3	22.2	28.0	33.8
10.5	17.5	23.7	30.0	36.2
11.0	18.7	25.3	32.0	37.7
11.5	19.9	27.1	34.3	41.4
12.0	21.3	29.0	36.7	44.4
12.5	22.5	30.7	39.0	47.1
13.0	23.7	32.3	40.9	49.5
13.5	24.8	34.0	43.0	52.2
14.0	26.2	35.8	45.4	55.2
14.5	27.7	37.9	48.2	58.5
15.0	28.8	39.5	50.3	60.9
16.0	31.6	43.3	55.2	67.0
17.0	34.3	47.2	60.1	73.0
18.0	37.0	51.0	65.3	79.0

Head over weir	*Width of weir*			
cm	*30 cm*	*40 cm*	*50 cm*	*60 cm*
19.0	39.8	55.0	70.0	85.0
20.0	42.8	59.3	75.8	88.8
21.0	45.7	63.3	81.0	99.0
22.0	48.7	67.5	86.7	105.7
23.0	51.3	71.7	92.2	112.3
24.0	54.7	76.5	94.8	120.0
25.0	57.0	79.8	102.7	125.8
26.0	60.3	84.6	109.2	133.3
27.0	63.5	89.2	115.0	140.8
28.0	66.5	93.7	122.2	148.3
29.0	69.5	98.3	127.0	155.7
30.0	72.5	102.7	133.0	163.3

Table 6.2.2 : Discharge through a 90°V-notch

Height of water over V-notch cm	*Discharge lit/sec*	*Height of water over V—notch cm*	*Discharge lit/sec*	*Height of water over V—notch cm*	*Discharge lit/sec*
4.0	0.45	13.0	8.6	22.0	31.0
4.5	0.60	13.5	9.5	22.5	34.0
5.0	0.80	14.0	10.5	23.0	35.7
5.5	1.0	14.5	11.3	23.5	38.2
6.0	1.2	15.0	12.3	24.0	40.0
6.5	1.5	15.5	13.3	24.5	42.7
7.0	1.8	16.0	14.5	25.0	44.5
7.5	2.2	16.5	15.5	25.5	46.7
8.0	2.5	17.0	16.7	26.0	48.8
8.5	2.8	17.5	18.3	26.5	51.0
9.0	3.4	18.0	19.4	27.0	53.8
9.5	3.9	18.5	21.7	27.5	56.3
10.0	4.5	19.0	22.3	28.0	58.7
10.5	5.1	19.5	23.5	28.5	61.5
11.0	5.7	20.0	25.5	29.0	64.5
11.5	6.3	20.5	27.0	29.5	66.8
12.0	7.1	21.0	28.3	30.0	69.4
12.5	7.8	21.5	30.3		

Table 6.2.3 : Free-flow discharge values for Parshall flumes

Head	*Discharge, (lit/sec)*			
	Throat width			
cm	*7.5 cm*	*15 cm*	*23 cm*	*30 cm*
3	0.8	1.4	2.6	3.1
4	1.2	2.3	4.0	4.5
5	1.7	3.3	5.5	7.0
6	2.3	4.4	7.2	9.6
7	2.7	5.4	8.5	11.4
8	3.5	7.2	11.1	14.4
9	4.3	8.5	13.5	17.7
10	5.0	10.2	15.9	21.1
11	5.8	11.6	18.1	23.8
12	6.7	13.5	21.1	27.5
13	7.5	15.0	23.3	31.0
14	8.5	17.3	26.7	35.0
15	9.4	19.2	29.5	38.7
16	10.4	21.2	32.5	42.7
17	11.4	23.2	35.6	46.7
18	12.4	25.3	39.0	51.2
19	13.6	27.8	42.5	55.0
20	14.3	30.0	45.8	59.7
21	15.8	32.7	49.3	64.7
22	17.1	35.2	53.3	69.8
23	18.2	37.7	56.8	74.0
24	19.4	40.1	60.5	79.0
25	20.7	42.7	64.5	84.1
26	22.0	45.7	68.3	89.0
27	23.3	48.1	72.4	94.3
28	24.8	51.5	76.7	100.0
29	26.0	54.0	80.7	105.1
30	27.5	57.3	85.2	111.0

v) USE OF ORIFICE PLATE :

For measurement of water flowing into individual plots or furrows, orifice plates may be used. Orifice plate is made by cutting a circular hole in a metal plate (Fig.6.2.3). The plate is portable and is installed by driving it into the ground at the upstream of a plot or furrow to be irrigated. The discharge through the orifice plate is dependent upon the diameter of the orifice and the head of water above the centre of the orifice. The orifice plate works most sastisfactorily under free overfall condition, though it can be used

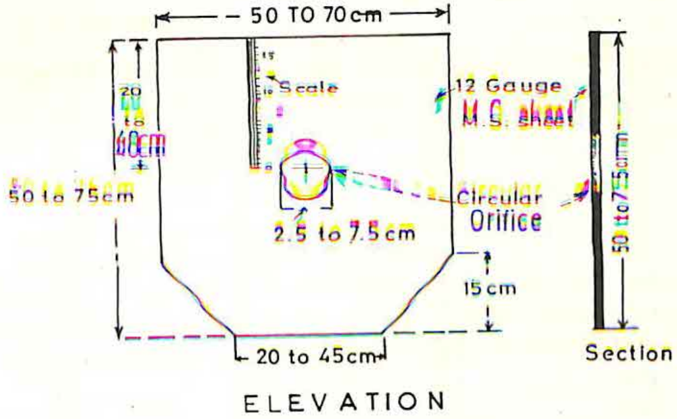

Fig. 6.2.3 DETAILS OF AN ORIFICE PLATE

under submerged flood condition also. The discharge through the orifice is calculated by the formula:

$$Q = 0.61 \times 10^{-3} a \sqrt{2gh}$$

Where : Q = discharge (lit./sec),
a = area of cross section of the orifice (cm^2),
g = acceleration due to gravity (981 cm/sec^2),
and h = head of water above the centre of the orifice (cm) in the case of a free overfall orifice.

Table 6.2.4 gives the discharges through orifices of different diameter under different heads.

Table 6.2.4.: Discharge through Circular Orifice

Height of water over centre of orifice	*Discharge rate, lit/sec*		
	Diemeter of orifice		
cm	*2.5 cm*	*5.0 cm*	*7.5 cm*
1.0	0.13	0.53	1.2
1.5	0.16	0.64	1.4
2.0	0.19	0.74	1.7
2.5	0.21	0.81	1.8
3.0	0.23	0.91	2.1
3.5	0.25	0.99	2.2
4.0	0.26	1.15	2.4
4.5	0.28	1.20	2.5
5.0	0.30	1.21	2.7
5.5	0.31	1.23	2.8
6.0	0.32	1.30	2.9
6.5	0.33	1.34	3.0
7.0	0.35	1.39	3.1

Height of water over centre of orifice cm	*Discharge rate, lit/sec Diemeter of orifice* 2.5 cm	5.0 cm	7.5 cm
7.5	0.36	1.45	3.3
8.0	0.38	1.50	3.4
8.5	0.39	1.53	3.5
9.0	0.40	1.60	3.6
9.5	0.41	1.62	3.7
10.0	0.42	1.70	3.8
10.5	0.43	1.72	3.9
11.0	0.44	1.75	3.9
11.5	0.45	1.80	4.0
12.0	0.46	1.83	4.1
12.5	4.47	1.87	4.2
13.0	0.48	1.90	4.3
13.5	0.49	1.93	4.4
14.0	0.50	1.96	4.5
14.5	0.50	2.01	4.5
15.0	0.51	2.05	4.6
15.5	0.52	2.08	4.7
16.0	0.53	2.12	4.80
16.5	0.54	2.15	4.83
17.0	0.54	2.19	4.92
17.5	0.55	2.22	5.00
18.0	0.56	2.25	5.13
18.5	0.57	2.28	5.15
19.0	0.58	2.31	5.20
19.5	0.58	2.34	5.30
20.0	0.59	2.37	5.32
20.5	0.60	2.40	5.40
21.0	0.60	2.43	5.47
21.5	0.61	2.46	5.53
22.0	0.62	2.49	5.60
22.5	0.63	2.51	5.65
23.0	0.63	2.54	5.70
23.5	0.64	2.57	5.77
24.0	0.65	2.60	5.83
24.5	0.66	2.62	5.92
25.0	0.66	2.65	5.95
25.5	0.66	2.68	6.00
26.0	0.67	2.70	6.10
26.5	0.68	2.73	6.12
27.0	0.69	2.75	6.18
27.5	0.69	2.78	6.23
28.0	0.70	2.80	6.30
28.5	0.71	2.83	6.37
29.0	0.71	2.85	6.40
29.5	0.72	2.88	6.47
30.0	0.72	2.90	6.53

vi) USE OF SIPHON TUBE :

Flexible PVC pipes or curved metal pipes can be used as siphons to convey water from irrigation channels to the plot or to individual furrows. The discharge through siphon tube is expressed as

$Q = 0.65 \times 10^{-3}\, a \sqrt{2gh}$

Q = discharge (lit/sec),

a = area of cross section of the siphon tube (cm^2),

g = acceleration due to gravity (981 cm/sec^2),

h = vertical distance between the outlet and the upstream water level in case of free overfall or the vertical distance between upstream and downstream water levels in case of submerged flow (cm).

vii) USE OF FLOAT :

The flow velocity in open channels can be roughly estimated by using a float. The float method of measurement is relatively inaccurate but is very simple in application. A float is a piece of wood approximately 2 cm × 2 cm with a thickness of about 0.5 cm. In the absence of such a piece, any small item that floats in water can be used.

To use the float method for velocity measurement a straight portion of the channel of uniform corss section is selected and two sections are identified at a distance of about 30 m. The float is gently placed on the middle of the channel section a few metres upstream to the beginning of the 30 m stretch. The time taken by the float to cover the distance between the two sections is noted and velocity is calculated. This is the surface velocity at the middle of the section. The mean velocity is calculated by multiplying the surface velocity by 0.85. The product of the mean velocity and the area of corss section of flow gives the discharge. If velocity is calculated in m/sec and area of cross section of flow in sq. metre, the discharge will be in cubic metre per second.

viii) USE OF ORIFICE METER, VENTURI METER AND WATER METERS :

These are instruments used to measure discharge under pipe flow condition. The orifice meter and venturi meter are difficult to use in the field and require further instrumentation. Water meters that are commonly available in the market can be coupled to the delivery pipe from a pump and the readings noted between a certain time interval. The dial of water is calibrated in terms of the volume of water passed through the meter. The volume divided by the time interval between two recordings gives the discharge rate. Usually water meters are not used to calculate the rate of flow but to supply a given volume of water to the area to be irrigated. Water meters are however expensive and, therefore, are not always feasible to be used.

ix) COORDINATE METHOD OF MEASUREMENT :

This method is used to measure discharge under pipe flow and when there exists a free overall from a horizontal pipe. This is a relatively inaccurate method and may be used for rough estimate only or when other items of measurement e.g. water meter, orifice meter, venturimeter, etc. are not available, or when volumetric measurement is not feasible due to heavy discharge and when a quick estimate of discharge is required.

Problem 1

The net irrigation requirement of 1 ha cropped area is 5 cm. The irrigation application efficiency is assumed to be 75%. The irrigation is to be delivered from a channel fitted with a 90^0V notch and a head of 20 cm over the V notch is ensured. Calculate the time required to irrigate the area.

Solution

Net irrigation requirement = 5 cm
Irrigation application efficiency = 75%
$\therefore$ Gross depth of water required = $5/75 \times 100 = 6.67$ cm

Volume of water required = $6.67/100 \times 100 \times 100$ (1 ha=100×100 m^2)
= 667 m^3 for one hectare of area.
Referring to table 6.2.2 the discharge over a 90^0 V notch for a 20 cm head = 25.5 lit/sec = $25.5/1000$ m^3/sec (1 m^3 = 1000 lit)
Time taken to irrigate 1 ha area=$667/25.5 \times 1000$ second
= $667 \times 1000/25.5 \times 3600$ hours (1 hour = 3600 seconds)
= 10.79 hrs, say 11 hours.
Thus it wil require 11 hours to irrigate one hectare area.

Problem 2

You have to advise a cooperative farm on the size of the Parshall flume they have to buy for monitoring the discharge in one of the open channels in the farm. By enquiry, you have ascertained that the maximum discharge will not exceed 40 lit/sec and the maximum depth of flow can not be allowed to exceed 30 cm.

Solution

By referring to the table 6.2.3 of discharges through Parshall flume, it is seen that 40 lit/sec discharge can be carried by a flume of 15 cm size at a head of about 24 cm, by a 23 cm flume at a head of about 18.5 cm and by a 30 cm flume at a head of about 15.5 cm. Since a larger size Parshall flume will cost more, your advise should be to buy a 15 cm Parshall flume. By using this flume we will not exceed the head of 30 cm. On the other hand a flume of 7.5 cm, although will be cheapest, it will require more than 30 cm head to pass a discharge of 40 lit/sec, which is not permissible.

Problem 3

A border strip, 2 m wide and 50 m long, is to be irrigated by applying a gross depth of 7.5 cm of water. The irrigation is to be completed in 30 minutes. The water is to be delivered by a siphon tube. The depth of water in the irrigation channel is 20 cm. The elevation difference between the channel bottom and the border is 5 cm. Find the diameter of the siphon tube required for irrigation?

Solution

Volume of water required for irrigation = $(50)\ (2)\ (7.5/100)\ m^3$
$= 7.5\ m^3$

Time for irrigation = 30 min. = 1800 seconds.
$\therefore$Required discharge(Q)= $7.5/1800 = 0.0042\ m^3/sec = 4.2$ lit/sec.
Effective head = (5+20) cm = 25 cm
Area of Siphon tube $= \pi/4\ D^2 = 0.785\ D^2$
Where: D is the diameter of the siphon tube in cm
$Q = (0.65)\ (A)\ (\sqrt{2gh}) \times 10^{-3}$
$\therefore 4.2 = (0.65)\ (0.785\ D^2)\ (\sqrt{(2)\ (981)\ (25)} \times 10^{-3} = (113)\ (D^2) \times 10^{-3}$
$\therefore D^2 = 4200/113 = 37.17$
$\therefore D = 6.1$ cm.

From the market the available pipe may be taken having the nearest diameter. If a 6 cm diameter pipe is available, the irrigation time will be slightly increased.

6.3 General precautions :

- Select a straight reach of the channel of uniform cross section for measurement of discharge or velocity.
- Record observations as mentioned in the manual given by the manufacturers when using current meter or Parshall flume.

- Ensure free fall for installation of weirs, notches, orifices, siphon, tubes, etc.
- Measure the head over the V-notch or rectangular weirs at least 4 times the depth of flood upstream to the weir.
- Ensure that the velocity of water prior to flow over weirs is as low as possible.

6a. Sub Unit : **Measuremet of Irrigation Water by Float Method**

6a.1 Precautions :

- Select a straight reach of uniform cross section of about 30 metre length.
- Ensure that there is no weed growth in the channel.

6a.2 Materials required :

i. Float
ii. Measuring tape
iii. Stop watch or a common watch with seconds needle
iv. Scale and point guage

6a.3 Procedure :

- Make a reach about 30 metre long with the measuring tape.
- Using the scale and point gauge, take measurements of top width at the water surface, bottom width and depth of water flow in the channel at several sections to arrive at an average cross sectional area of water flow.
- Place the float in the centre of the channel, 1 to 2 metre upstream of the start of the measured length.
- Record the time taken by the float to travel the marked length of the channel.
- Repeat the process four times to obtain an average reading.

6a.4 Observations :

The pupil should record the following observations :

— Length of the reach selected (L) = ... m
— Time taken by float to travel the distances (t) = ... seconds

— Cross sectional area of the channel (A) = ... m^2

6a.5 Calculations :

The pupil should calculate the rate of flow as per formulae given below :

$$V = 0.85\ L/t$$

$$= 0.85 \times \frac{\text{length of the reach in metre}}{\text{time to cover the reach in seconds}}$$

$$Q = A \times V$$

Where : Q = Rate of flow, $m^3\ Sec^{-1}$
A = Cross sectional area of the flow, m^2
V = Mean velocity of water flow in the channel, m/sec.

6b. Sub Unit : Measurement of Discharge from a Horizontal Pipe with Free Overfall (By Coordinate method)

6b.1 Precautions :

- Select the horizontal delivery pipe from a pump.
- Ensure free overfall condition.
- Select a point on the nappe of water such that the ratio of horizontal distance of this point from the pipe edge to the diameter of the pipe is greater than 5.

6b. 2 Materials required :

i. Scales
ii. Vernier caliper

6b.3 Procedure :

- Select a point at the upper surface of the nappe of water coming out from a horizontal pipe, when the nappe has travelled some distance and has curved downwards.
- Measure the horizontal distance (X) of this point from the edge of the pipe.
- Measure the vertical distance (Y) of this point from the top of the pipe and subtract the pipe thickness from this value.

- Measure the internal diameter of the pipe with a vernier caliper.

(For X and Y refer (Fig. 6b.3.1)

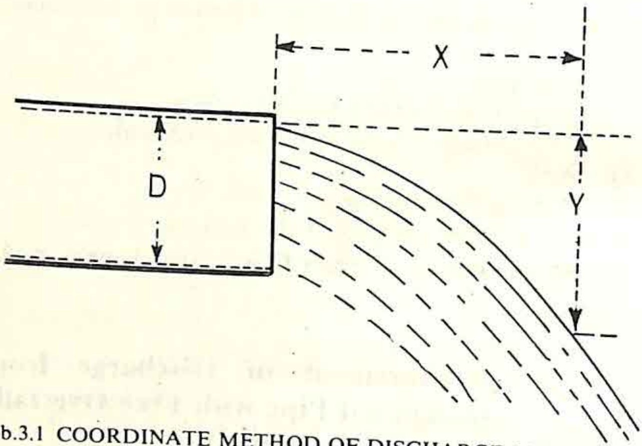

Fig. 6b.3.1 COORDINATE METHOD OF DISCHARGE MEASUREMENT

6b.4 Observations :

The pupil should record the followings :

- Horizontal distance of the selected point on the nappe from the pipe edge (X) = m
- Vertical distance of the point from the upper surface of the pipe (Y^1)= m
- Thickness of the pipe material (y) = m
- Diameter of the pipe (D) = m

6b.5 Calculations :

The pupil should calculate the following :

- Vertical distance of the selected point from the top inner edge of the pipe (Y) = (Y^1 - y) = m
- Area of the pipe (A) $= \pi/4 \times D^2$

$= 0.785 \times D^2 = ... m^2$

- Discharge (Q) $= CA \times \sqrt{2g} / \sqrt{2Y}$

Where : Q = discharge ($M^3 \ sec^{-1}$)

X; Y = As defined earlier (m)

A = Cross sectional area of the pipe (m^2)

g = Acceleration due to gravity (9.81 m/sec^{-2})

C = Coefficient assumed to be 1 for rough estimate of discharge for X/D >5.

6.4 Expected behavioural outcomes :

The pupil will be able to :

- explain the necessity of measuring water flow in a pipe;
- explain the principles of water measurement;
- compare the different types of flow measuring devices;
- measure the flow;
- advise the farmers/users on the type and size of flow measuring device required for their field situations.

Grade

The teacher should evaluate the pupil for the above abilities.

6.5 Questions :

i. What are the different flow measuring devices?

ii. Under what channel conditions are knotches and weirs used?

iii. When is coordinate method of water measurement used?

iv. In an exercise to determine the discharge in an open channel by float method, the following data were obtained:
Channel is trapezoidal with bottom
width (b) = 20 cm
Depth of flow (y) = 30 cm
Side slopes (Z) = 1.5
Time taken by the float to cover a distance of 30 m = 25 sec.
Calculate the discharge in the channel.

v. In measuring discharge through a free flowing horizontal pipe fitted to a pump, the following data were obtained:
Horizontal distance of a point on the upper surface of the nappe from the pipe edge (X) = 40 cm
Vertical distance of the point from the top inner edge of the pipe (Y) = 10 cm,
Pipe diameter (D) = 7.5 cm
Assume C = 1
Calculate the discharge.

7. Activity Unit

DETERMINATION OF IRRIGATION EFFICIENCIES

7.1 Instructional objectives :

The pupil should be able to :

— explain the meaning of irrigation efficiencies;

— recall the significance of irrigation efficiencies;

— recall how to improve irrigation efficiencies;

— determine irrigation application and distribution efficiencies.

7.2. Relevant information :

— What are irrigation efficiencies?

Irrigation efficiencies are the parameters which indicate how best the water applied to the farm is being utilized. These parameters are needed to know the performance of the irrigation activity on the farm. There are four common irrigation efficiencies. These are application efficiency (Ea), storage efficiency (Es), distribution efficiency (Ed) and water use efficiency (WUE). Ea, Es and Ed are expressed as percentages and WUE is expressed as the economic yield of crop per unit area, per unit of water consumptively used by the crop and is usually expressed in the unit kg/ha. cm. If we consider the irrigation distribution network, i.e. distributaries, water courses, etc., then water conveyance efficiency (Ec) is used to find out what percentage of the released water at the head actually reaches the farm and is an indicator of the seepage loss in the conveyance channels. The overall irrigation efficiency for a farm is the product Ea×Es×Ed. The overall irrigation efficiency for a project (i.e. considering the irrigation channel) is the product Ea×Es×Ed×Ec. The concepts of Ea, Es and Ed have been explained schematically in Fig. 7.2.1.

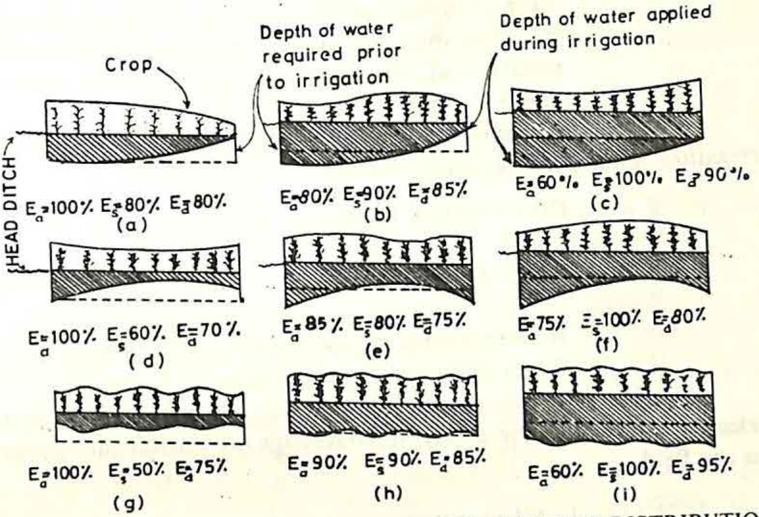

Fig. 7.2.1 CONCEPTS OF APPLICATION, STORGAE AND DISTRIBUTION EFFICIENCY

i. APPLICATION EFFICIENCY (Ea)

It is expressed as : $Ea = Ws/Wf \times 100$

Where :

Ws = Water stored in root zone (cm),

Wf = Water applied to the field (cm).

A low application efficiency implies that much of the applied water has been lost due to deep percolation or runoff.

ii. STORAGE EFFICIENCY (Es)

It is expressed as ;

$Es = Ws/Wu \times 100$

Where :

Ws = Water stored in the root zone (cm),

Wu = Water needed in the root zone (cm).

A low storage efficiency implies that water application is much less than actually needed.

iii. WATER DISTRIBUTION EFFICIENCY (Ed)

It is expressed as :

$Ed = (1 - \bar{y}/\bar{d}) \times 100$

where :

d = Average depth of water stored in the crop root zone after irrigation (cm),

$\bar{y}$ = Average numerical deviation in the depth of water stored in the crop root zone (measured at selected points from the irrigated plot) from the average depth d, (cm).

A low distribution efficiency means non-uniformity in the irrigation water penetration in the soil.

iv) WATER CONVEYANCE EFFICIENCY (Ec)

It is expressed as :

$Ec = Wf / Wd \times 100$

Where :

Wf = Water available for application to the farm, lit / sec.

Wd = Water delivered from the source, lit / sec.,

A low conveyance efficiency implies that much of the water released from the source is lost due to seepage in transit from source to the field.

v) WATER USE EFFICIENCY (WUE)

It is expressed as :

$WUE = Y / Wcu$

Y = Crop yield in (kg/ha),

Wcu = Water consumptively used by the crop (cm).

— *Significance of irrigation efficiencies*

A low value of any of the irrigation efficiencies in general implies that the land, water and the crops are not being managed properly. A low application efficiency means wastage of water in the form of deep percolation or runoff losses. This happens due to improper land preparation, too little slope, excessive stream size, excess application of water than is actually needed. A poor storage efficiency means water has been applied inadequately. In a stretch of land one may get poor application efficiency for the upstream part and poor storage efficiency for the down stream section. A poor distribution efficiency results due to uneven land surface. The irrigation water cannot flow over the soil smoothly. There are low patches where water will penetrate more and there are high patches where water cannot reach. A low water use efficiency also results due to over application of water or inability of the crops to utilize the applied water due to poor vegetative growth or due to adverse chemical properties of the root zone soil and water. The net effects of poor irrigation efficiencies are crop loss, and wastage of water and nutrients.

— *Principal factors affecting irrigation efficiency*

- — Design of irrigation system,
- — quality of land preparation,
- — selection of irrigation methods,
- — stream size,
- — slope of land,
- — skill and care of irrigator.

— *Steps to increase irrigation efficiencies*

— Select proper method of irrigation.

This will depend on the type of crop, available stream size and topography. The general guidelines for increasing efficiencies in surface methods of irrigation application are :

a) For border irrigation in heavy soils and mild slope (upto 0.05%), the border width may be 7-8 m and stream size 10-12 lit/sec. For medium soils and slopes from 0.05 to 0.1%, the border width may be 6-7 m and stream size 12-15 lit/sec. For light soil with 0.2 to 0.5% slope, the border width may be 5-6 m and stream size 15-20 lit/sec.

b) For check basin irrigation in heavy soils, the basin size may be 200-240 sq. m for stream size of 4 lit/sec and 350-400 sq. m for stream size of 28 lit/sec. For medium soil, the size may be 100-125 sq. m for stream size of 14 lit/sec and 150-180 sq. m for stream size of 20 lit/sec. For light soil, the basin size may be 16-20 sq. m for a stream size of 14 lit/sec and 20-25 sq. m for a stream size of 28 lit/sec. The plots may be square or rectangular. For rectangular plots, the length to width ratio should not be more than 4.

c) For furrow irrigation in heavy soils, the furrow length may vary from 300 to 400 m; in medium soil, from 120 m to 300 m and in light soil from 60 to 20 m. The ranges are for slopes varying from 0.05% to 1% and for depth of application from 5 cm to 10 cm. For mild slope and less depth of water application, the furrow lengths are shorter. For steeper slopes and larger depth of application, the furrows are longer. The stream size for furrow varies from 0.5 to 2.5 lit/sec, and may be calculated by an empirical formula.

$Q = 0.6/S$

Where :

Q = Stream size in lit/sec.
S = Furrow slope in per cent.

— *Examples to evaluate irrigation efficiencies*

Problem 1

A border 4 m wide and 75 m long was irrigated by a stream size of 10 lit/sec . for one hour. Soil samples taken before irrigation from the root zone (assumed to be 1 m) indicated a moisture content of 30% by volume. Again, average soil moisure 48 hours after irrigation indicated a soil moisture of 40% by volume. The evapotranspiration loss is 4 mm/day. There was no runoff loss. Find the application efficiency.

Solution ·

Volume of water applied = 10/1000 × 60 × 60
= 36 m^3
= 36 / 4× 75 = 0.12 m = 12cm

Moisture held in root zone before irrigation
= 30 cm per meter depth.

Moisture held in root zone 48 hours after irrigation
= 40 cm per metre depth.

Moisture stored in root zone = 40-30
= 10 cm

Since evapotranspiration loss is 4 mm/day, the water lost in two days between irrigation and soil moisture measurement = 8 mm
= 0.8 cm

Actual quantity of water available for storage in the root zone
= Water applied - water lost due to evapotranspiration
= 12 - 0.8 = 11.2 cm

∴ Application efficiency = Water stored in root zone / Water applied
= 10 / 11.2 = 89.3%

Problem 2

A stream of 15 lit/sec is used to irrigate an area of 5 m × 100 m under furrow irrigation. The moisture deficit in 1 m root zone is 5 cm. The irrigation is applied for half an hour and then stopped. There was no runoff loss. At 5 places in the field, average soil moisture was determined 48 hours after irrigation and was found to be 6 cm, 5 cm, 3 cm, 2 cm, and 5 cm per metre depth of soil. Calculate the distribution efficiency, storage efficiency and application efficiency. Neglect evapotranspiration.

Solution

Water needed in the root zone = 5 cm
Average depth of water stored in the
root zone after irrigation = $6+5+3+2+5 / 5$
= $21/5 = 4.2$ cm.

The deviation in depth of water stored from the average depth 4.2 is the numerical difference between the two, for each of the 5 points and is : 1.8 cm, 0.8 cm, 1.2 cm, 2.2 cm and 1.2 cm.

∴ Average numerical deviation $= \overline{Y}$
$= 1.8 + 0.8 + 1.2 + 2.2 + 1.2/5 = 7.2 / 5$
$= 1.44$ cm

∴ Distribution efficiency $= (1 - 1.44 / 4.2) \times 100 = 65.7\%$
Storage efficiency = Water stored / Water needed × 100
$= 4.2 / 5 \times 100 = 84\%$
Water applied $= 15/1000 \times 3600 \times \frac{1}{2} = 27\ m^3$
$= 27 / 5 \times 100 = 0.054\ m^3 = 5.4$ cm
∴ Application efficiency = Water stored / Water applied × 100
$= 4.2 / 5.4 \times 100 = 77.7\ \%$

7.3 Precautions :

- Give particular care to land preparation. Lay border and furrows on uniform slope. Avoid cross slope in borders. Smoothen all local depressions or high points by using suitable land shaping equipment.
- Avoid irrigation for very long durations and over irrigation.
- Maintain the shapes of irrigation channels, furrows, borders and basins.
- Give frequent but smaller depth of irrigation in light soils and vice-versa in heavy soils.
- Give light irrigation at germination and initial stage of crop growth.
- Take care to eliminate runoff loss.

7.4 Materials required :

i. Balance
ii. Soil auger
iii. Moisture boxes
iv. Oven
v. Water measuring device
vi. Spade
vii. Stop watch Water measuring device

7.5 Procedure :

- Obtain soil samples at different depths from the root zone before irrigation and determine existing depth of soil moisture.
- Use any available water measuring device and find out the amount of water applied to the field during irrigation.
- After 48 hours of irrigation when downward percolation has ceased, collect soil samples at different depths of the soil profile at different places spread over the area and find out the moisture contents.

7.6 Observations :

The pupil should take the following observations :

— Depth of moisture in the root zone before irrigation (X) = cm
— Depth of moisture in the root zone after irrigation (Y) = cm
— Amount of water applied (Z) = cm

7.7 Calculations :

The pupil should use above data and calculate the application efficiency by using the following formula:

Application efficiency (E_a) = $(Y - X) / Z \times 100$

7.8 Expected behavioural outcomes :

The pupil will be able to :

- compare the different irrigation efficiencies and their significance;
- get an idea for improving irrigation efficiencies;
- compute irrigation efficiencies.

Grade

The teacher should evaluate the pupil for the above abilities.

7.9 Questions :

i. Name the different irrigation efficiencies.
ii. What do you understand by a) poor application efficiency and b) good distribution efficiency?
iii. How irrigation efficiencies can be improved?

8. Activity Unit

DETERMINATION OF WATER REQUIREMENT OF CROPS

8.1 Instructional objectives :

The pupil should be able to :
- assess the total water need of a crop;
- explain the contribution of irrigation water, rainfall and profile moisture to the total water requirement;
- compute the irrigation water required for meeting the consumptive use of water (CU), unavoidable application losses and water required for meeting special needs of crop;
- work out the irrigation requirements of the crop.

8.2 Relevant information :

— *What is water requirement ?*

It is the total quantity of water required to mature an adequately irrigated crop. It includes the water applied to the crop through irrigation as well as that received through natural rainfall, utilized from the stored soil moisture in the root zone, and ground water contribution, if any. Water requirement includes the quantity of water needed to meet the consumptive use of water of the crop (CU), unavoidable losses (L) and the additional quantities of water needed for leaching of salts below the crop root zone, land preparation, transplanting, frost control, etc.

Water requirement (WR) of crops, considering it as a demand can be expressed as :

WR = CU+Application losses + Special needs.

It can also be expressed in supply terms as given below :

$$WR = IR + ER + S + G$$

where :

IR = Total depth of irrigation water during crop growth.

ER = Effective rainfall during crop growth.

S = Profile water use i.e., the difference in moisture content in the root zone at the beginning and end of the crop.
G = Ground water contribution, if any.

— *What is consumptive water use?*

It is the quantity of water used by a crop in evaporation and transpiration (ET) and that used by the plants in their metabolic processes from a particular area during a specified time. For all practical purposes, CU is taken as equal to ET, since the amount of water used in metabolic processes is negligible (Fig. 8.2.1).

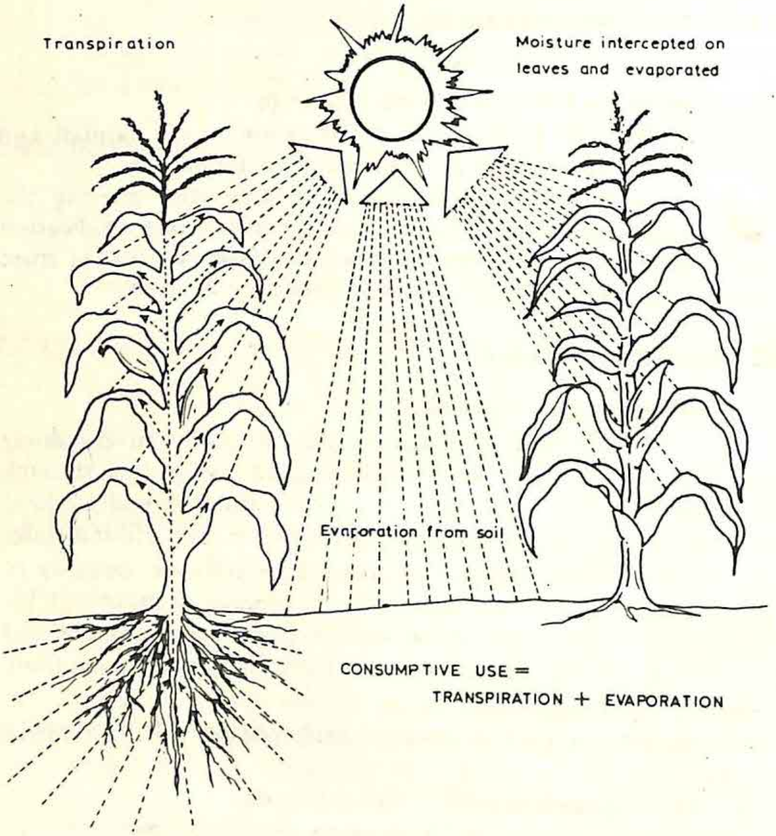
Transpiration
Moisture intercepted on leaves and evaporated
Evaporation from soil
CONSUMPTIVE USE =
TRANSPIRATION + EVAPORATION

Fig. 8.2.1 DIAGRAM SHOWING CONSUMPTIVE USE

The knowledge of computation of water requirement of crops (WR) is essential as it forms the basis for :

- effective utilization of water in the field.
- planning the cropping pattern and intensity of cropping on a farm in relation to the availability of water resources.

— *What is effective rainfall?*

It is that fraction of total rainfall which is useful for meeting crop water requirement; it excludes the fraction lost in deep drainage and runoff.

— *An example to compute water requirement of different crops*

The data collected in the following table help in calculating the water requirements.

Crop	*No. of irrigations*	*Total depth of water applied (cm)*	*Effective rainfall (cm)*	*Contribution from soil profile (cm)*	*Contribution from ground water, if any (cm)*	*Seasonal water requirement (cm)*
1	2	3	4	5	6	7
Wheat	5	37.5	5.3	2.0	nil	54.8
Rice (Low land)	10	60.0	70.8	2.5	—	133.3
Maize	2	15.0	33.3	3.5	4.2	56.2
Grain Sorghum	nil	—	25.0	15.0	—	40.0
Gram	1	7.5	7.2	18.0	—	32.7

Note : i. Values under columns 3 and 4 are for the entire crop growing season.
ii. Under inadequate water supply, the value of WR reflects the water expense

— *Factors affecting water requirement of crops*

Factors affecting crop water requirement can be groupped into three categories, those influencing (a) consumptive water use, (b) unavoidable water losses, and (c) additional water needs incidental to raising of crops.

a) CONSUMPTIVE WATER USE :

These include factors related to climate, soil and crop characteristics.

Among climatic factors, high solar radiation, high temperature, high wind velocity and low relative humidity cause increased ET from the cropped field and vice versa. Rainfall influences water availability to crops and hence the ET.

Among soil factors, texture, structure and soil depth are most important. They influence primarily water storage in soil and its release to meet the ET demand of the crop. In general, coarse textured soils retain and transmit less water and hence need more frequent irrigations which lead to high evaporational loss of water and higher consumptive use. Poor structured soils, because of low infiltration rate, require greater time of water ponding which causes more evaporational loss. Water storage in soil is directly related to its depth which may be limiting either due to the presence of some hard pan in the soil profile or parent rock.

Crop species and varieties differ in their growth characteristics and hence in their ET demand. Important crop characteristics are nature and development of canopy; leaf orientation as well as type and distribution of stomata on the leaves and the extent of waxy coating and type, distribution and depth of rooting.

b) UNAVOIDABLE WATER LOSSES :

Unavoidable water losses are related to the water discharge rate. In general, they are more under canal irrigation followed in order by tubewells and open dug wells. Irrigation methods also influence unavoidable losses. In general, where there is a greater control in water application such as by drip and sprinkler, the losses are less as compared to surface methods of irrigation. In the latter, water losses are less in case of furrow irrigation as compared to check basin or border irrigation. Irrigation management is another important factor influencing such losses. Over irrigation causes higher water loss. Soil type and surface configuration also influence water losses. Losses are more in coarse textured soils and in uneven fields.

c) ADDITIONAL WATER NEEDS :

With increase in salt concentration in the root zone, more water is needed for leaching of salts. The amount of water required for land preparation will also depend on the antecedent moisture in the field, previous cultivation practices and surface roughness. In case of rice culture, a large amount of water is required for land preparation and puddling of the field.

8.3 Precautions :

- Take special care to calculate the effective rainfall for each shower, keeping in view the moisture status in the root zone.
- Take periodic observations on depth to water table if it is shallow.

8.4 Materials/information required :

The pupil should collect the data on :

- total depth of irrigation water applied during the crop season including that given for meeting the special needs of the crop;
- moisture content in the root zone (cm) at sowing and at harvest of the crop;
- amount of rainfall, datewise;
- daily pan evaporation of the locality.

8.5 Procedure :

- Work out the total amount of water applied through irrigation including that given for meeting the special needs of crop.
- Work out the difference in soil moisture contents in the root zone at sowing and harvest.
- Work out the total effective rainfall for the season.

— *Effective rainfall computation :*

CASE I FOR ADEQUATELY IRRIGATED UPLAND CROPS :

- For this, work out the cumulative pan evaporation from the data of last irrigation/rainfall.
- Multiply it by a factor of 0.7-0.8 to get an approximate estimate of evapotranspiration (ET) depending on the nature of crop and its stage of growth. If the calculated value is higher than the amount of rainfall during the period, take the entire rainfall as effective.
- In case the rainfall exceeds the calculated value for the period, take effective rainfall equal to estimated value and neglect the rest.

CASE II FOR LOW LAND PADDY :

- If the rainfall received is less than the difference between the existing water depth and the upper limit of the standing water (approx. 10 cm.) in the field, take it as effective rainfall. Rainfall in excess to this difference would be ineffective.

8.6 Observations and Calculations :

The pupil should take the following observations and calculate the seasonal water requirements of different crops.

Farm :
Village :
District :
Crop :
Year :
Tube well/canal distributary discharge capacity.

Crop	*No. of irrigations*	*Total depth of water applied (cm)*	*Total effective rainfall (cm)*	*Soil moisture in the root zone, depth*		*Contribution from the profile (5-6)*	*Seasonal water requirement (cm) (3+4+7)*
				At planting (cm)	*At harvesting (cm)*		
1	2	3	4	5	6	7	8

Note : i. Values under columns 3 and 4 are for the entire crop growing season.
ii. Under inadequate water supply the value of WR reflects the water expense.
iii. Ground water contribution be assumed zero, if it is deeper than 2m from the surface.

8.7 Expected behavioural outcomes :

The pupil will be able to :

- work out the water requirement (WR) of crops;
- explain the different components of total WR of different crops;
- get an idea of irrigation requirement of crops.

Grade

The teacher should evaluate the pupil for the above abilities.

8.8 Questions :

i. Define water requirement of crops.

ii. What do you mean by effective rainfall?

iii. Which one of the following crops has the highest water requirement and which one the lowest (tick one):
   - a) Bangal gram
   - b) Maize
   - c) Wheat
   - d) Grain Sorghum
   - e) Paddy

iv. Under which of the following conditions, the contribution of the stored soil profile moisture will be the highest? (Tick one):
   - a) frequently irrigated crops
   - b) less frequently irrigated crops
   - c) dryland crops

v. The water requirement of a good wheat crop will be around (tick one):
   a) 5 cm b) 25 cm c) 50 cm d) 75 cm

vi. Compute the water requirement of the mustard crop with the help of the following data :
   - a) Total. moisture storage in root zone at sowing= 28 cm
   - b) Total moisture in root zone at harvest. = 18 cm
   - c) Effective rainfall = 3.9 cm
   - d) Irrigation water applied = 14.0 cm

vii. Give reasons for the following :
   - a) Evaporation of water from the soil surface is higher in frequently irrigated crop than in less frequently irrigated crop.
   - b) Water requirement of a summer crop would be more than that of a winter crop of the same duration.

viii. Which one of the following components would be reduced by mulching? (Tick one):
   - a) Evaporation
   - b) Transpiration.

9. Activity Unit

IRRIGATION AT CRITICAL GROWTH STAGES IN WHEAT CROP

9.1 Instructional objectives :

The pupil should be able to :

- explain the criteria for scheduling irrigation to crops;
- explain what is meant by critical growth stage;
- recall the different stages of growth in various crops;
- identify the critical growth stages with respect to water needs in wheat crop;
- learn the harmful effects of missing irrigation at critical growth stages.

9.2. Relevant information :

— *Criteria for for scheduling irrigation to crops*

Irrigation is applied to a crop to prevent or minimise reductions in growth and yield resulting from severity of plant water stress. In case of adequate water supply, irrigation can be scheduled to a crop according to soil, plant or climate based criteria. Important soil based criteria for scheduling irrigation are (a) point measurement of soil moisture tension (SMT) with a tensiometer installed at a specified depth and, (b) determination of permissible depletion of plant available water by periodical measurement of soil water status by gravimetric method or neutron scattering method. Usually tensiometers are installed at a depth of 45 to 60 cm depending on rooting pattern of crops and the soil texture, and when they indicate 0.5 to 0.6 bar SMT, a specified amount of irrigation water is applied. In case of depletion approach, irrigation is applied at 50% depletion of the plant available water in the zone of maximum root concentration. In case of plant based criteria, irrigation can be applied to a crop on occurrence of symptoms like drooping, curling or change of colour of leaves. A better alternative is to apply irrigation at various growth stages of a crop which can be easily identified. Irrigation can also be applied by measuring plant water stress in terms of leaf water potential, leaf diffusion resistance and leaf temperature, but as these measurements require costly and highly sophisticated equipment, they are not commonly used.

Climate based criteria involve estimation of potential evapotranspiration (PET) and actual evapotranspiration (ET) using climatic data from which irrigation requirement over a given period is worked out. Such estimation is cumbersome. A better alternative is to use the pan evaporation data (Ep) for scheduling irrigation. Usually, IW/CEp ratio of 0.7 to 0.9 is used for scheduling irrigation where IW is the depth of irrigation water to be applied and CEp is the cumulative pan evaporation. When water supply is limited, crops have to encounter water deficit during their growth. However, by applying irrigation to crops at those growth stages which are most sensitive (critical) to water deficit, yield reduction will be minimised despite overall water deficit. Critical growth stages differ from crop to crop (Table 9.2.1). Incase of wheat, growth stage coincident with

Table 9.2.1. : Some commonly identifiable crop growth stages and critical stage* for water needs in various crops

Crop	*Growth stages*					
	1	2	3	4	5	6
Wheat	C.R.I.*	Late tillering	Jointing/ boot	Flowering	Milk	Dough
Maize	2-3 leaf	Knee-high	Tasseling*/ silking	Cob development	—	—
Grain sorghum	3-4 leaf	*Preheading	Flowering	Grain development	—	—
Groundnut	Branching	*Flowering to pegging	Pod development	—	—	—
Mustard (raya)	Branching	* Flowering to Pod development	—	—	—	—
Gram and other grain legumes	Branching	* Flowering	Pod development	—	—	—
Paddy	—	Tillering*	—	—	Flowering*	—

* denotes the most critical stage

crown root initiation has been found critical. Identification of crown root initiation stage in wheat is an important exercise.

— *What is meant by critical growth stage?*

It refers to the stage/stages of crop growth at which moisture shortage leads to severe reduction in growth and yield.

— *Critical growth stages in different crops*

Almost all the field crops are highly sensitive at a certain growth stage to moisture deficit i.e. they suffer high yield reduction. Therefore, such stage at which the missing of an irrigation results in the irrevocable loss in yield is considered critical. Some commonly identifiable critical crop growth stages for water needs in various crops are shown in Table 9.2.1.

— *Identification of the critical growth stage in wheat*

In wheat the crown root initiation (CRI) stage has been identified as the most critical. If the irrigation at this stage is missed, it causes irrepairable losses in yield mainly due to reduction in tiller number. The secondary roots known as crown roots, are developed at 2 cm depth below the soil surface. This layer normally gets dried up within a few days after sowing. For the initiation and proper development of crown roots, adequate moisture in the top layer (0-2 cm) is essential.

9.3 Precautions :

- Collect whole plant samples carefully without damaging any roots.
- Closely observe the development of the secondary roots i.e., crown roots.
- Observe the development of roots at frequent intervals (1-2 days) from 15 days onwards after sowing.
- Observe root development in larger number of plant samples.

9.4 Materials required :

i. Two plots of the size 5 m × 2 m
ii. Irrigation source
iii. Metre scale
iv. Spade
v. Wheat seeds
vi. *Khurpi* or hand hoe

9.5 Procedure :

- Prepare two plots of size 5 m × 2 m each.
- Sow wheat seeds of a particular variety in lines.
- After 15 days of sowing collect 10 whole plant samples with a *Khurpi* or hand hoe taking care not to damage any roots.
- Wash the roots and observe the development of crown roots.
- Record the number of plants showing crown root initiation.
- Repeat the observation on growth of crown roots at frequent intervals (1-2) days till it has developed in 50 per cent of the plant samples.
- Record the date when 50 per cent plant samples bear crown roots. Count the number of days taken to reach crown root initiation stage.
- Irrigate Plot I on this day (crown root initiation stage).
- Do not irrigate plot II at this stage.
- Continue further irrigation in both the plots at late tillering, jointing, flowering, milk and dough stages.
- At 60 days after sowing earmark 1 metre row length in the centre of the second row on one side of the plot with pegs.
- Select five plants at random from the 1 m row length and tag them.
- Record the height of tagged plants with a metre scale.
- Count the number of tillers/metre row length.
- At the time of harvest count the number of ears from the 1 metre row length earmarked for record of plant height and number of tillers.
- Take the yields of grain and straw (Kg/plot).

9.6 Observations and Calculations :

The pupil should record the following observations and calculate the yield of grain and straw.

	Plot I	Plot II
— The time of crown root development, days		
— Growth parameters at 60 days after sowing :		
a) Plant height (cm)		
b) No. of tillers/metre row length		
— Yield attributes at harvest :		
a) Number of ears/metre		
b) Yield of grain (gm^{-2})		
c) Yield of straw (gm^{-2})		

9.7 Expected behavioural outcomes :

The pupil will be able to :

- explain the criteria for scheduling irrigation to crops;
- recognise the important growth stages of different crops;
- recognise critical growth stages of crops with respect to irrigation;
- assess the adverse effects of missing irrigation at the critical growth;
- make best use of limited irrigation water supply by irrigating crops at the critical growth stages.

Grade

The teacher should evaluate the pupil for the above abilities.

9.8 Questions :

i What are the 6 physiological stages for irrigating wheat crop? Indicate the most critical one.

ii. What is meant by 'critical crop growth stage' in respect of irrigation?

iii. At what depth in soil are the crown roots in wheat initiated?

iv. Put tick mark (✓) in the correct one :

a) Primary roots in wheat are the main feeding roots : Yes/No

b) The crown roots in wheat initiate after about :
   a) 15 days after sowing
   b) 21 days after sowing
   c) 35 days after sowing

v. Enlist the important critical stages of the following crops with respect to irrigation?
   a) Maize
   b) Groundnut
   c) Mustard

vi. What are the merits of scheduling irrigation on the basis of crop growth stages?

10. Activity Unit

CONVEYANCE OF IRRIGATION WATER IN CHANNELS AND THROUGH PIPES

10.1 Instructional objectives :

The pupil should be able to :

- compare open channel flow and pipe flow;
- learn to calculate the carrying capacity in open channels and diameter of pipe for a given discharge;
- explain about types of lining used to reduce seepage loss from open channels;
- construct and lay out prefabricated cement concrete channels.

10.2 Relevant information :

— *Pipe flow and open channel flow*

An open channel flow is one where the water surface is open to atmosphere. A pipe flow is one in which the water is flowing through a closed conduit and pressure of water is more than one atmosphere.

— *Classification of open channels*

Open channels are usually rectangular, trapezoidal or parabolic in shape. The most common shapes are the rectangular and trapezoidal. The selection of a particular type of shape depends on constructional facilities, cost of construction, type of lining etc.

— *Carrying capacity of open channels*

For calculating the carrying capacity, it is required to estimate the mean velocity of flow by using Manning's formula :

$V = 1/n\ R^{2/3} S^{1/2}$

Where: V = Mean velocity of flow (m/sec),

N = Manning's roughness coefficient,

R = Hydraulic radius = A/P (m),

A = Wetted area (m^2),

P = Wetted perimeter (m),

S = Channel bed slope in fraction.

The Manning's roughness coefficient is dependent upon the degree of resistence offered to the flow of water by the channel sides and channel bottom. Following table (10.2.1) may be used as a guidelines to select a proper value of n.

Table 10.2.1: Manning's roughness coefficient

Channel description	*Value of n*
Straight clean earth channel	0.022
Straight earth channel with some vegetation growth	0.030
Cement plastered channel	0.011
Concrete with good finish	0.013
Unfinished concrete	0.017
Brick in cement mortar	0.015

The values of A, P, and top width T for some common sections are given in the following table.

Table 10.2.2: Geometrical properties of some channel sections

Section	*Area A*	*Wetted perimeter P*	*Top width T*
Rectangular	$b. y$	$b+2y$	b
Trapezoidal	$by+zy^2$	$b+2y\sqrt{z^2+1}$	$b+2zy$

In the above table, z is the side slope of the channel expressed as horizontal : vertical. Thus, z = 1½ will mean that the channel has a side slope of 1½ horizontal : vertical , b is the bottom width of the channel and y is the depth of flow.

Some usual value of z are given below in the following table.

Table 10.2.3: Acceptable side slope for channel in different materials

Material forming the channel	*Side slope*
Stable rock	Vertical (z=O)
Stiff clay	½ : 1 (z=½)
Sandy loam	1½ : 1(z= 1½)
Lined channels	Verticuler 1 : 1 to 1½ : 1 (Z=O or 1-1½)

The channel bed slope is mainly governed by the local topography.

The mean velocity of flow as obtained from Manning's formula when multiplied with the area of cross section of flow, gives the carrying capacity of the channel.

Problem :

A trapezoidal channel has a bottom width of 20 cm, depth of flow 20 cm and side slope 1 : 1. The Manning's roughness coefficient is 0.013. Calculate the discharge flowing through the channel, if the channel is laid on a slope of 0.16%.

Solution

First We calculate the mean velocity of flow.

$V = 1/n \, R^{2/3} S^{1/2}$

$$R = A/P = \frac{by + zy^2}{b+2y\sqrt{z^2+1}} = \frac{(20)(20) + (1)(20)^2}{(20) + (2)(20)\sqrt{1+1}} = \frac{800}{76.56}$$

$= 10.4 \text{ cm} = 0.104 \text{ m}$

$V = 1/0.013 \, (0.104)^{2/3} (0.0016)^{1/2} = 0.68 \text{ m/sec.}$

Calculate the dishcharge by :

$Q = A \times V = 800/100 \times 100 \times 0.68 = 0.037 \text{ m}^3/\text{sec.}$

$= 37$ lit/sec.

— *Carrying capacity of pipes*

Irrigation water can be conveniently carried through pipeline system. The maintenance problems are minimum in this system of conveyance and the area lost due to construction of open channels is also saved. The water from the source is let into the pump stand and flows through the pipe line. In conveying water through pipelines certain amount of energy of flowing water is required to overcome frictional resistance offered by the pipe wall. If it is assumed that the water is delivered from the end of the pipeline at atmospheric pressure, then the velocity of flow in the pipe can be calculated by using the formula :

$$V = \sqrt{hdg/2fl}$$

Where : V = velocity of flow of water in the pipe (cm/sec),

h = difference in elevation of water levels at the pump stand and at the outlet (cm),

d = diameter of the pipe (cm),

l = length of pipe (cm),

g = acceleration due to gravity=981 cm/sec^{-2},

f = friction factor.

The friction factor is a variable one and is related to diameter of pipe, velocity of flow and condition of pipeline. A rigorous solution will, therefore, have to be done by trial and error or by referring to tables of relation between V, d and f for different types of pipes. For the present case, however 3 values of are given, one for galvanised iron pipe, one for cast iron pipe and the third for concrete pipe.

Table : Average value of friction factor for diameter range from 15-30 cm and velocity range of 30-90 cm/sec.

Material of pipe	*Value of f*
Galvanised iron	0.0044
Cast iron	0.0055
Concrete pipe	0.0074

After the velocity has been calculated by using the above formulae, the diameter is calculated from the information of discharge and velocity.

Problem 2

A pump is delivering water at the rate of 40 litres per second into a sump. The water is carried 200 m away through an underground concrete pipe line laid at a slope of 0.1%. The water is discharged through a riser at atmospheric pressure. The water level in the sump is 1 m above the ground surface and the riser 200 m away is discharging water at the ground level. Calculate the diameter of the pipe required to convey the water.

Solution

Actual elevation difference between the water level at the sump and the water level at the riser

= 1 m +gain in head due to 0.1% slope in 200 m length.
= 1.2 m = h. $L = 200$ m, $f = 0.0074$

$$\therefore V = \sqrt{\frac{(1.2)\,(d)\,(9.81)}{(2)\,(0.0074)\,(200)}} = 1.997\ \sqrt{d}\ \text{m/sec.}$$

$Q = 40$ lit/sec.. $=40/1000 = 0.04\ \text{m}^3/\text{sec.}$

$Q = A.V. = \pi/4\ d^2.\ V$ or $0.04=(0.785)\,(d^2)\,(1.997)\sqrt{d)} = 1.565\,(d)^{5/2}$

or $(d)^{5/2} = 0.0256$.: $d = (0.0256)^{2/5} = 0.2308$

From the market availability viewpoint, one may select a pipe of 22.5 cm diameter. This will cause a little rise in water level in the stand pipe.

Problem-3

Determine the discharge capacity of an underground pipeline from the following data :

Pipe diameter $D = 15$ cm; difference in water level between the sump stand and the delivery side $h=3$, assumed value of friction factor, $f = 0.008$; length of pipe = 300 cm.

Solution

$$V = \sqrt{hdg/2\,fl}$$
$$= \sqrt{(3)\,(15)\,(981)\;/\;(2)\,(0.008)\,(3.00)}$$
$$= 96 \text{ cm/sec.}$$

Area of pipe $A = \pi/4\,(D)^2 = (0.785)\,(15)^2 = 176.63 \text{ cm}^2$

$$Q = A \times V = 176.63 \times 96 = 16956.5 \text{ cm}^3/\text{sec} = 0.017 \text{ m}^3/\text{sec.}$$
$$= 17 \text{ lit/sec.}$$

— *Lining of irrigation channels*

Irrigation channels are lined primarily for the purpose of reducing seepage losses and to improve the carrying capacity of the channel by reducing the value of roughness coefficient. The lining also helps in proper maintenance at a lesser cost and if maintained properly, the weed growth problems are minimized.

There are many types of linings such as brick masonry with pointing or plastering, lining by stone slab with cement mortar joints, concrete lining, polyethylene lining, clay lining, using prefabricated concrete channel section, etc. The lining work starts with the preparation of the sub base over which the lining is to be done, selecting the type of lining on the basis of cost, availability of material, ease of construction, etc., and then execute the lining work. Pre-fabricated channels are built in reinforced or non-reinforced channels usually 1 m long at almost rectangular cross section and may be made in different sizes. These are easy to construct and can be constructed by a village artisan or by the farmer himself. These are relatively cheaper in comparison to most of the other linings.

— *Advantages of prefabricated channel*

- It is simple to fabricate and can be fabricated by the farmer himself.
- The cost of construction is low as compared to other types of lining of channels.
- It is particularly suitable for handling comparatively low discharges.
- It minimizes seepage loss and prevents erosion in the channel.
- It provides safety against breaks, reduces weed growth, controls damage by rodents, etc.

— It reduces amount of land occupied since side embankments as for earthen channels are not required.
— It reduces labour requirement for channel maintenance.

— *Types of pre-fabricated channel sections*

Pre-cast concrete channel sections may be of two types :

a) Semi-circular sections—The semi-circular channels or 'half pipes' are made especially for irrigational use by commercial manufacturers of concrete pipe.
They are made in lengths of one metre or more and are generally 30 to 45 cm in diameter.

b) U-shaped section—These are low-cost concrete sections made in a U-shaped wooden form by tapping in a concrete mixture made with a bare minimum of water.

The wooden form (mould) is made through local carpenter (Fig.10.2.1). Hard wood boards, 2.5 cm thick are used to make the form. Removable pins at corners permit removal of forms without disturbing the newly cast section. The size of the form depends on the size of the irrigation stream to be conveyed.

— *Discharge capacity of prefabricated channels*

The discharge capacity of prefabricated channels is determined by using Manning's formula the use of which has been explained earlier in the section. The value of n in Manning's equation may be taken between 0.013 and 0.017 depending on the finish. For the inner surface with a good finish obtained by brushing the inside surface with cement slurry, the value of n will be 0.013. For the surface where such treatment has not been given, the value of n may be taken as 0.017. Table 10.2.1. gives the discharge in prefabricated channel laid on different slopes and having different sizes. In calculating this table, the value of n has been taken as 0.015. Since the pre-fabricated channel sections have good utility for on-farm water conveyance, their method of construction and layout are given in subsequent sections.

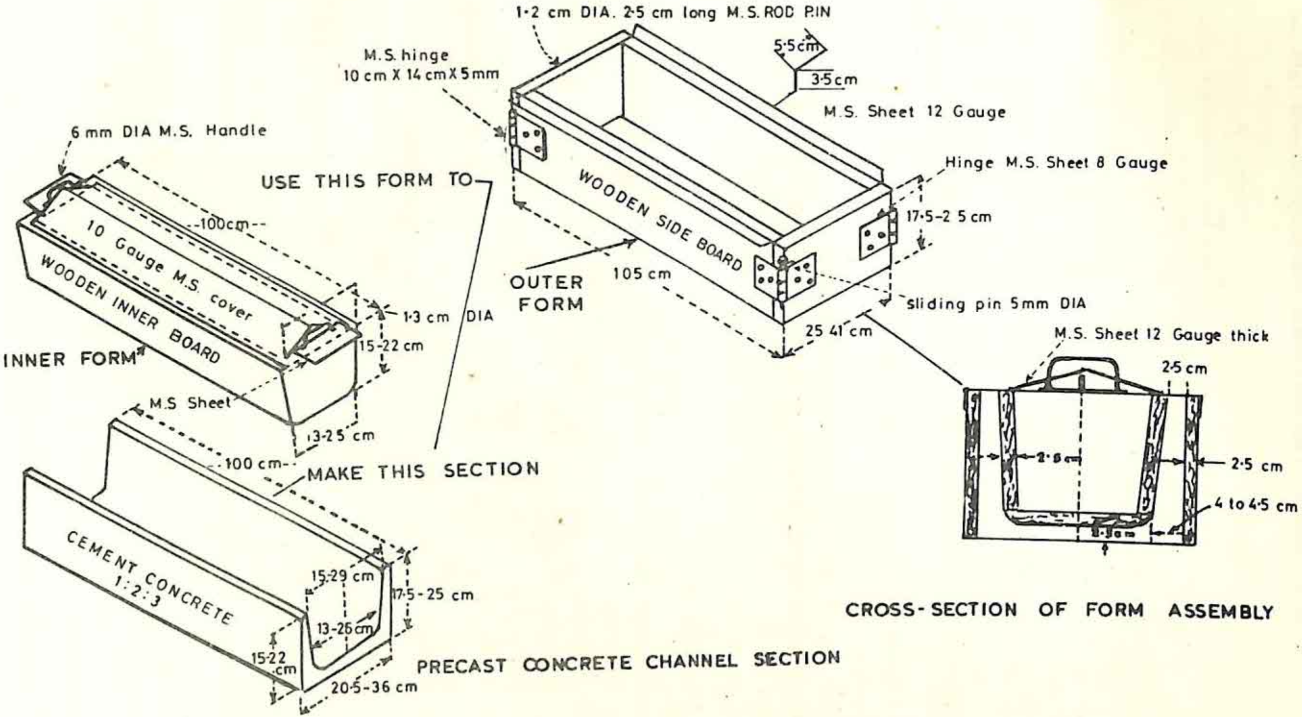

Fig. 10.2.1 WOODEN FORM TO MAKE PRECAST CONCRETE CHANNEL SECTION

Source : Michael, A.M. *et at* (1970) Hand Book of Farm Irrigation Structures

Table 10.2.1: Discharge capacity of pre-cast concrete channels (Roughness coefficient n=0.015)

Channel	*Discharge, lit/sec.*						
section	*Channel bed slope, per cent*						
Average width x depth (inside)	*0.1*	*0.2*	*0.3*	*0.4*	*0.6*	*0.8*	*0.10*
14.5 × 15 cm	6.2	8.7	10.7	12.3	15.1	17.4	19.5
17.0 × 18 cm	9.7	13.7	16.7	19.1	23.6	27.2	30.4
19.0 × 20 cm	12.9	18.4	22.4	25.6	31.7	36.5	40.8
21.5 × 22 cm	17.4	24.7	30.1	34.6	42.5	49.1	54.9
24.5 × 22 cm	20.8	29.6	36.1	41.4	51.0	58.7	65.8
27.0 × 22 cm	23.9	34.1	41.5	47.6	58.6	67.6	75.6

— *Construction and layout of prefabricated concrete channel section*

The precast channels are cheaper to make and easy to operate. Hence, methods for their construction and layout should be learnt by the pupil.

10.3 Precautions :

- Ensure that the size of gravels is smaller than one centimetre diameter.
- Add only minimum quantity of water necessary to make the mixture workable.
- Do not allow the mixture to dry for a long time in the frame.
- Slide out the side boards slowly without damaging the freshly cast section.
- Protect the concrete sections from sun or rain for 24 hours.
- Cure the new concrete section properly by sprinkling water frequently.
- Prevent leakage through the section by coating with thin cement slurry.
- Select desired channel bed slope while laying out the sections.
- Join precast concrete sections with cement mortar (1 cement : 2 sand).
- The joints of the sections should be cured by sprinkling/ponding water.

10.4 Materials required :

i. Wooden frame having outer and inner forms

ii. Cement, sand and gravel
iii. Water
iv. Steel rod
v. Oil (waste or used oil)
vi. Piece of cloth

10.5 Procedure:

10.5a Construction of precast concrete sections

- Prepare a concrete mixture of cement, sand and gravel in the ratio of cement:sand:gravel (1:2:3)
- Add minimum quantity of water necessary to make the mixture workable.
- Apply a very light coating of the oil with a piece of cloth on inner side of outer form and outer sides and bottom of inner form.
- At first, place the outer form over a thin layer of sand spread on a level ground.
- Put a 2.5 cm thick concrete layer to form the bottom and tamp it (Fig.10.5a.1).

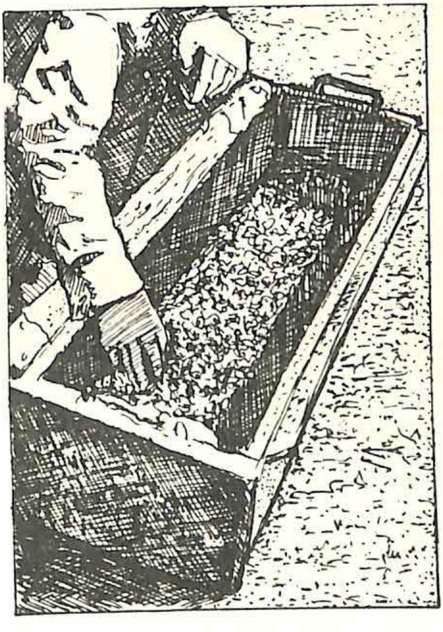

Fig. 10.5a.1 SPREADING A 2.5 cm THICK CONCRETE LAYER AT THE BOTTOM OF THE OUTER FORM

- Place the inner wooden form over the concrete bed.
- Fill the side gaps with concrete mixture.
- Tamp the concrete mixture into the form with a steel rod (Fig. 10.5a.2).

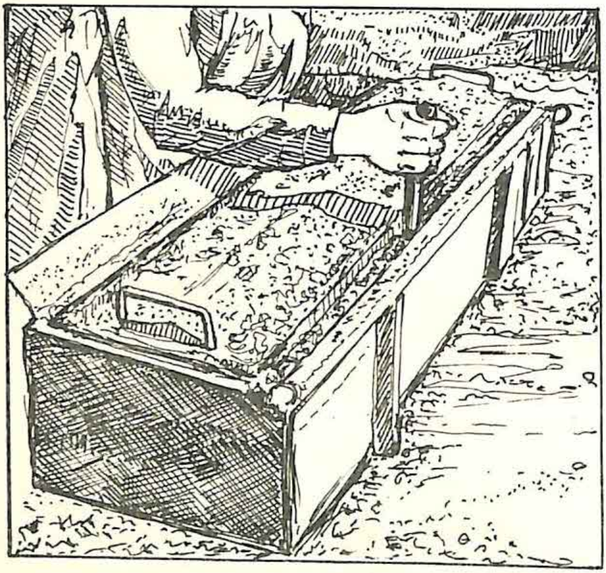

Fig. 10.5a.2 TAMPING CONCRETE IN THE SIDE SPACE OF THE FORM WITH AN IRON ROD

To remove the form, lift the inner form slowly (Fig. 10.5a.3).

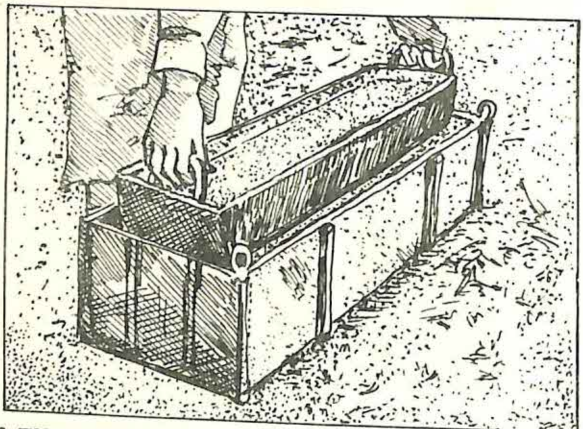

Fig. 10.5a.3 THE INNER FORM IS LIFTED AND REMOVED AFTER THE CONCRETE IS TAMPED IN THE FORM

- Then remove the pins of the outer form and slide out the side boards slowly without damaging the freshly cast section (Fig. 10.5a.4).

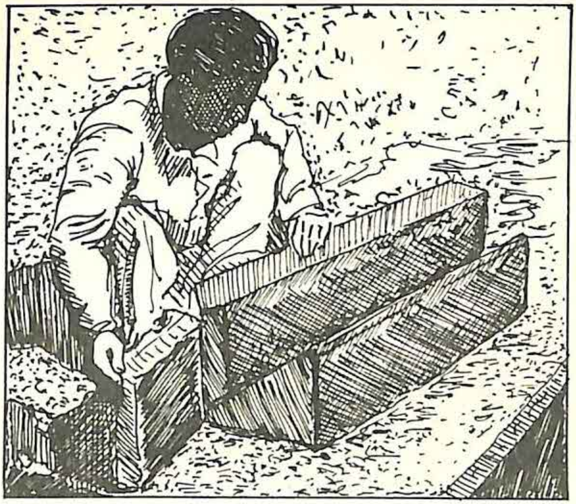

Fig. 10.5a.4 THE SIDE BOARDS ARE SLIDE OUT SLOWLY AFTER THE INNER FORM IS REMOVED

- Protect the new concrete section from sun and rain for about 24 hours.
- Then cure concrete section for over a week by sprinkling water frequently.
- After curing, coat the inside of the channel section with a thin cement slurry to prevent any leakage through the section (Fig. 10.5a.5).

10.5b Laying out of concrete section

- First make a suitable small earth embankment.
- Compact the embankment while moist to obtain the desired bed slope.
- Lay the precast concrete section in a straight line.

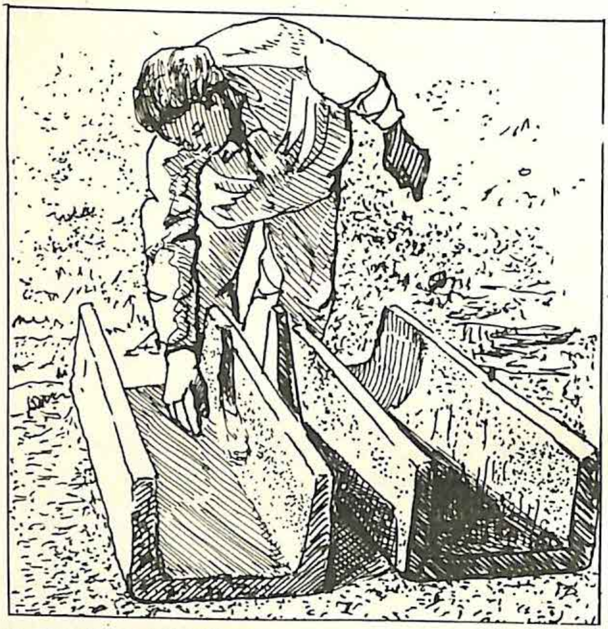

Fig. 10.5a.5 COATING THE INSIDE OF A PRECAST CHANNEL SECTION WITH CEMENT SLURRY

- Then fill the joints of the sections with cement mortar having a ratio (1 cement : 2 sand). (Fig. 10 .5b.1).
- Cure the joints by sprinkling water frequently for 2 to 3 days or by ponding water in the newly laid channel.

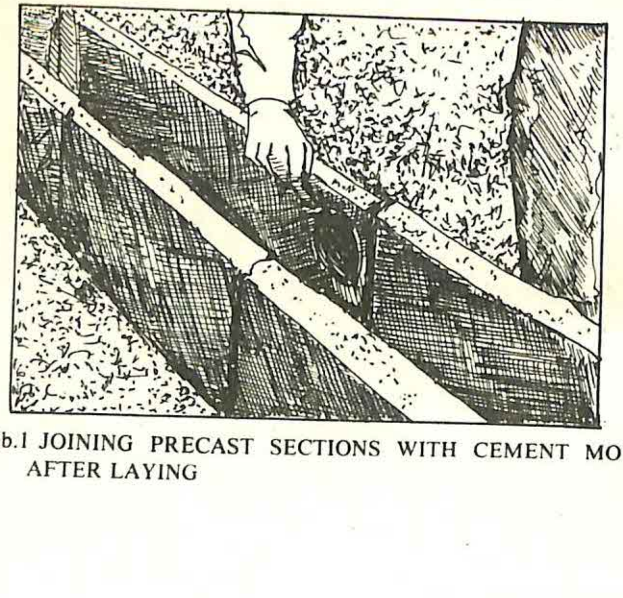

Fig. 10.5b.1 JOINING PRECAST SECTIONS WITH CEMENT MORTAR AFTER LAYING

10.6 Observations :

The pupil should take the following observations :

- Whether there is any breakage or cracking of joints due to uneven attachment of base.
- Whether there is any leakage.

10.7 Expected behavioural outcomes :

The pupil will be able to :

- explain how water can be conveyed on the farm through open channel and pipe lines;
- recall different types of lining and purpose of lining;
- make or advise for making prefabricated concrete channel sections;
- layout prefabricated channel sections

Grade

The teacher should evaluate the pupil for the above abilities.

10.8 Questions :

i. What is Manning's equation? What for is it used? Define all the terms in Manning's equation.
ii. What are the common shapes of open channels? How will you calculate the cross sectional area, hydraulic radius and wetted perimeter of these sections?
iii. What is Manning's roughness coefficient? Give approximate values of n for lined and unlined channel.
iv. How a prefabricated concrete channel section is constructed and laid?
v. What information is required to calculate the required pipe diameter for carrying a known discharge?
vi. What information is required to calculate the carrying capacity of a pipe?
vii. What are the advantages of a prefabricated channel?

11. Activity Unit

DETERMINATION OF IRRIGATION WATER QUALITY

11.1 Instructional objectives :

The pupil should be able to :

- recall about the soluble salts present in water;
- measure soluble salts present in water;
- judge the quality of water;
- find out whether the water is normal, saline or sodic;
- recall the tolerant and resistant crops;
- use the poor quality water in crop production.

11.2 Relevant information :

— *Soluble salts*

All waters contain dissolved salts which are added to the soil with the application of each irrigation. When the applied water evaporates from the soil surface or transpires through plants, the salts are left in the soil. This is a continuous process. The continuous accumulation of salts in the soil in due course will make it difficult for the crops to grow. Therefore, a salt balance in the soil has to be maintained through proper water management practices for continuous and successful cultivation of crops.

— *Methods to determine the quality of irrigation water*

There are three important methods for determining the quality of irrigation water.

a) TOTAL SOLUBLE SALTS

The important anions present in the irrigation water are $CO_3^{=}$, HCO_3^{-}, $SO_4^{=}$ and Cl^{-} and the cations are Na^{+}, Ca^{++}, Mg^{++} and K^{+}. Salinity of water refers to concentration of total soluble salts in it. Sodicity of water indicates the proportion of sodium in the total soluble salts. The Concentration of soluble salts in water are indirectly measured by its electrical conductivity (EC). The quality of saline waters has been divided into five classes as per USDA classification given as under:

Salinity Class	*Electrical conductivity*	
	Micro mhos/cm	*Millimhos/cm*
C_1 Low	< 250	< 0.25
C_2 Medium	250 to 750	0.25 to 0.75
C_3 Medium to high	750 to 2250	0.75 to 2.25
C_4 High	2250 to 5000	2.25 to 5.00
C_5 Very High	> 5000	> 5.00

Similarly irrigation waters have been divided into the following four classes according to the concentration of sodium measured as Sodium adsorbtion Ratio (SAR)

$$SAR = Na^+ / \sqrt{(Ca^{++} + Mg^{++})/2}$$

The ion concentration is expressed as meq-l.
The various sodocity classes of water are as under :

Sodium class	*SAR value*
S_1 Low	< 10
S_2 Moderate	10 to 18
S_3 High	18 to 26
S_4 Very high	> 26

b) RESIDUAL SODIUM CARBONATE (RSC)

The Residual Sodium Carbonate (RSC) in irrigation waters is determined as given below :

$$RSC = (CO_3^{=} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

According to the RSC irrigation waters have been classified as under :

Safe = 1.25 meq^{-l}
Marginal = 1.25 to 2.50 meq^{-l}
Unsuitable = 2.50 meq^{-l}

c) BORON CONTENT :

Boron is an important soluble ion in irrigation water and can become toxic to plant growth. The limits of boron content for three categories of crops are given on the next page.

Permissible Limits of Boron Content

Class	*Permissible boron content limits in ppm*		
	Sensitive crops	*Semi tolerant crops*	*Tolerant crops*
1. Safe	< 0.33	< 0.67	< 1.0
2. Medium	0.33 to 0.67	0.67 to 1.33	1.0 to 2.00
3. Toxic	0.67 to 1.00	1.33 to 2.00	2.0 to 3.00
4. Highly toxic	1.00 to 1.25	2.00 to 2.50	3.0 to 3.75

— *Why to use poor quality of water?*

The problem of salty waters is predominent in arid and semi-arid areas. In such areas in absence of canal water, ground water which is saline is the only source of water for crop raising. Under inadequate canal water supply it becomes a supplementary resource..

— *Factors affecting the use of poor quality water*

There are number of factors affecting the use of poor quality water in crop production. The important ones are :

a) TEXTURE OF THE SOIL :

Coarse textured soils which are highly permeable allow salts to move deep into the profile. Therefore, waters which are unsuitable for fine textured soils can safely be used in former soils.

b) CROP TOLERANCE :

The crops differ in their tolerance to poor quality of waters. A list of field crops, fruit crops, vegetable crops and forage crops with their relative tolerance is given in Table 11.2.1. It is clear from the table that the water which is unsuitable for susceptible crops in a particular type of soil may be used for other crops.

The use of saline water in relation to the susceptibility of the crop and the texture of soil is given in Table 11.2.2.

— *Methods of using poor quality water :*

a) DILUTION OF POOR QUALITY WATER WITH GOOD QUALITY WATER:

This is possible only in areas where good quality water is also available simultaneously with the poor quality of water. The proportion of the two can be worked out on the basis of the quality of two waters, type of soil and the crop for which the water has to be used.

Table 11.2.1. Relative salt tolerance of crop plants

Tolerant	*Semi-tolerant*	*Sensitive*
	FRUIT CROPS	
Date palm	Pomegranate	Apple
Guava	Fig	Orange
	Grape	Plum
	Mango	Almond
		Peach
		Strawberry
		Lemon
	VEGETABLE CROPS	
Turnip	Tomato	Radish
Spinach	Cabbage	Peas
	Cauliflower	Ladies finger
	Potato	
	Carrot	
	Onion	
	Cucumber	
	Brinjal	
	FIELD CROPS	
Sugarbeet	Sorghum	Moong
Barley	Maize	Urd
Dhaincha	Paddy	Gram
Cotton	Sunflower	Linseed
Safflower	Wheat	Beans
	Bajra	Sunnhemp
	Jowar	
	Arhar	
	Mustard	
	Tobacco	
	FORAGE CROPS	
Bermuda grass	*Senji*	
Rhodes grass	Oats	
Berseem		

b) ALTERNATIVE IRRIGATION STRATEGY :

There are certain crops as cotton which are susceptible at the time of germination, but tolerant at later stage. If germination and seedling establishment is ensured with good quality water, they can be irrigated with poor quality water during subsequent stages. However, only medium salinity water can be used in such a way.

Under inadequate canal water supply poor quality ground water can be used for irrigation alternating with it.

11.2.2 Water Quality Ratings

Nature of Soil	*Crop to be grown*	*Upper Permissible limit of EC of water for safe use for irrigation micromhos/cm*
Deep Black soils and alluvial soils having a clay content more than 30% : soils that are fairly moderately well drained.	Semi tolerant Tolerant	1500 2000
Heavy textured soils having a clay contents of 20-30% : soils that are well drained internally and have a good surface drainage system.	Semi-tolerant Tolerant	2000 4000
Medium textured soils having a clay contents of 10-20% : soils that are very well drained internally and have a good surface drainage system.	Semi-tolerant Tolerant.	4000 6000
Light textured soils having a clay content of less than 10% : soils that have excellent internal and surface drainage	Semi-tolerant Tolerant	6000 8000

c) RESTRICTED USE OF SALINE WATER :

In areas where saline water is the only source of irrigation, of low water requirements can successfully be raised, with limited application of irrigation water. Whatever salts are added through these irrigations are leached down during rainy season, maintaining a safe level of salt content in the root zone depth of the soil. Barley is an example of such crops.

In certain areas even the highly saline waters (EC=10 m mhos/cm) are used for raising a crop but only once in 3 to 5 years and in permeable soils. The salts added during one growing season through irrigation are allowed to leach down in 3 to 5 years time by scanty rain and no crop is raised during this period.

11a. Sub Unit : **Determination of Electrical Conductivity of the Irrigation Water**

11a.1 Relevant information :

— *Utility of Electrical Conductivity :*

Electrical conductivity is commonly used for indicating the total concentration of the soluble salts in natural water. It is a rapid and reasonably precise way to determine the total concentration of salts in water.

11a.2 Precautions :

- Do not use the solubridge without voltage stabilizer.
- Wash the conductivity cell thoroughly with distilled water after each sample reading.

11a.3 Materials required :

i. Solubridge or any other conductivity bridge
ii. Conductivity cell with platinum electrodes
iii. 0.01 N potassium chloride solution (0.7456 gram of dry KCl dissolved in the litre of distilled water at 25°C)
iv. Chromic acid (dissolve small amount, say 5 gram potassium dichromate in 100 ml water and add a few drops of sulphuric acid).
v. Irrigation water samples
vi. Beakers
vii. Wash bottle containing distilled water

11a.4 Procedure :

- Clean the conductivity cell with chromic acid and wash with distilled water.
- Adjust the resistance at 25°C.
- Rinse the cell with the irrigation water sample of which the EC is to be determined.
- Take fresh sample in the beaker (about 30 ml in 50 ml beaker), dip the cell and record the resistance of cell (R).
- Wash the conductivity cell with distilled water and repeat the processes for the next sample.

Calculate the electrical conductivity as follows :

$$EC = KR$$

Where : K = Cell constant
R = Cell resistance

11a.5 Observations :

The pupil should record the following observations :

Irrigation water sample number	*Resistance (R) milli ohms*	*Conductivity in micro-micromhos/cm at 25^0C* $= 1 \times 10^3 \;/\; R \times K$
1.		
2.		
3.		
4.		
5.		
6.		
7.		

11a.6 Interpretations :

The pupil should interpret the quality of irrigation water samples as per table given in the relevant information 11.2.

Quality of water	*Irrigation water sample number*
i. Good water	
ii. Slightly saline water	
iii. Moderately saline water	
iv. Saline water	
v. Highly saline water	

11b. Sub Unit : **Estimation of Total Soluble Salts (TSS)**

11b.1 Relevant information :

The total soluble salts can be estimated by the following formula

$$TSS = EC \times 10^6 \times 0.64$$
$$= \text{EC in micro mhos/cm} \times 0.64 \text{ mg/l}$$

The suitability of irrigation water can also be judged on the basis of total soluble salts. Though the suitability of water depends on the texture of the soil and its initial salt content, the following standards can be used for general references.

Sl. No.	*Concentration of soluble salts* *mmhos/cm*	 *Per cent TSS*	*Water quality*
1.	<1.5	<0.096	Fresh, normal, non-saline water of high quality
2.	1.5 to 3.0	0.096 to 0.192	Slightly saline, good quality water.
4. 3.	3.0 to 5.0	0.192 to 0.32	Moderately saline water to be used with safety measure.
4.	5.0 to 10.0	0.32 to 0.64	Saline, poor quality water to be used rarely with all precautions.
5.	10.0 to 15.0	0.64 to 0.96	Highly saline, poor quality water, normally should not be used for irrigation.
6.	>15	>0.96	Toxic water unfit for irrigation

1 micro mhos/cm = 1 mhos/cm × 10^3

11b.2 Interpretations :

The pupil should interpret the observation recorded in 11a.5.

Irrigation water sample No.	*Values of EC in m mhos/cm*	*Per cent total soluble salt (TSS)*	*Quality of water*

11.3 Expected behavioural outcomes :

The pupil will be able to :

- analyse the irrigation water for quality (Electrical conductivity and total soluble salts);
- assess the quality of water when chemical analysis of the irrigation water samples is made available in respect of :
  - a) total soluble salts
  - b) sodium adsorbtion ratio
  - c) residual sodium carbonate
  - d) boron content;

Grade

suggest the use of saline water based on :
a) texture of the soil,
b) susceptibility of the crop.

The teacher should evaluate the pupil for the above abilities.

11.4. Questions : —

i. What do you understand by poor quality of water?
ii. How can you judge the poor quality water?
iii. What are the important cations and anions present in the form of soluble salts in the water?
iv. Give the safe limits of salinity of irrigation water in terms of electrical conductivity and total soluble salts.
v. Name two important field crops and horticultural crops grown in your area which are :
  a) resistant to salinity,
  b) susceptible to salinity
vii. Give the equation for estimating RSC. What are its toxicity limits?
viii. What are toxicity limits of boron content for susceptible and tolerant crops?
ix. Do you think a water which cannot be used for irrigating a wheat crop in a clay soil can be used in a sandy soil, if so, why?
x. What do you understand by dilution of water?
xi. Write in brief the various methods that can be used for making use of poor quality water.

12. Activity Unit

MEASUREMENT OF DEPTH TO WATER TABLE

12.1 Instructional objectives :

The pupil should be able to :

- — explain the meaning of water table;
- — explain the importance of measurement of depth to water table;
- — recall the harmful effects of high water table;
- — measure depth of water table.

12.2 Relevant information :

— *What is water table?*

The upper surface of the zone of underground water is called the water table.

— *Fluctuation in water table*

The water table is not a stationary surface but moves up and down; rising where more water is added to the saturated zone by vertical percolation and dropping during drought periods when the previously stored water flows towards springs, stream, wells, and other points of ground water discharge. The is the reason why water table fluctuates from season to season.

— *Harmful effects of high water table*

High water table affects crop growth as it :

- — increases soil salinity and alkalinity;
- — restricts root growth;
- — restricts aeration to plants; and
- — affects water and nutrient uptake adversely.

— *Beneficial effects of high water table*

Good quality shallow ground water may become beneficial to crops as it contributes to their consumptive water use if it does not restrict aeration and root growth significantly.

— *Importance of measurement of depth to water table* .

Measurement of depth to ground water table provides information which is useful in :

- — laying out of surface and sub-surface drainage systems;
- — determining the depth of irrigation water;
- — controlling soil salinity build up ; and
- — selecting crops capable of growing under shallow water table conditions.

— *Selection of crops suited to high water table conditions*

Where water table is high,growing sensitive crops like maize, cotton, legumes, oilseeds, vegetables, tubber and root crops should be avoided. Instead, tolerant crops like paddy, sugarcane, grapes, cereals and jute *(Capsularies species)* may be chosen.

— *Methods of measurement of ground water table*

Ground water table can be measured by installing observation wells which are perforated, open ended pipes. In absence of observation wells, water table can be recorded in open wells.

12a. Sub Unit : Measurement of Ground Water Table in Observation Well

12a.1 Precautions :

- — Select such depth of bore in which fluctuations of water table can be measured through out the year.
- — Protect the observation well with cement concrete or hard soil layer around it.
- — Cover the open end of the observation well with a rubber stopper, metal lid or with plastic bag so that rain water or soil cannot get into it.
- — Take readings at fixed intervals and times.

12a.2 Materials required :

i. Post hole auger

ii. Observation well (Perforated G.I. Pipe of about 2.5 to 4.0

cm diameter)

iii. Graduated metal rod of about 5 mm diameter or an electric sounder with a cable, or a measuring tape with 10 cm long hollow metal pipe attached to its one end.

12a.3 Procedure :

- Select a representative spot in the field which will not be disturbed during cultivation or other field operations.
- Bore a hole with a post-hole auger till free ground water is reached in the soil profile.
- Increase the bore depth by 1.0 m or more below ground water level.
- Insert the perforated pipe into the bore touching the bottom.
- Keep at least 10 cm of the metal pipe above the ground surface.
- Close the open end with a stopper or a plastic bag.
- Insert graduated metal rod and measure the depth to water level from the surface by seeing the wet mark on the rod.
- Or, insert the cable of the electric sounder. As soon as it touches the water table, hear the sound and note the cable reading.
- Or, insert the measuring tape with hollow metal pipe into the observation well and when it touches the water level, a sound is heard. Note the reading on the tape.

12a.4 Observations :

The pupil should take the following observations at weekly intervals as per the table below :

Sl. No.	*Date*	*Time interval*	*Depth to water table (cm)*	*Rise or fall of water table (cm)*	*Remarks*
1.					
2.					
3.					
4.					
5.					
6.					
7.					

12a.5 Calculations :

The pupil should calculate the depth to water table as given below :

Length of metal rod or tape from the top of observatior well to water level = X .... cm

Length of observation well above the ground surface = Y ...cm

Depth of water table = (X–Y) = ... cm

12b. Sub Unit : Measurement of Depth to Water Table in Open Well

12b.1 Precaution :

- Make it sure that the place where you stand for taking the measurement near the open well is hard and stable.

12b.2 Materials required :

Measuring tape with a 10 cm long metal rod attached to its one end or an electric sounder or a graduated metal rod of about 5 mm diameter.

12b.3 Procedure :

- Lower the measuring device in the open well down the water level at a fixed interval and time.
- Record the depth to water.
- Record the height of well rim from ground surface and deduct it from the above measured depth to ground water.

12b.4 Observations :

The pupil should record the observations as per the table below:

Serial No.	*Date*	*Time interval*	*Depth to water table (cm)*	*Rise & fall of water table (cm)*	*Remarks*
1.					
2.					
3.					
4.					

12.3 Expected behavioural outcomes :

Grade

The pupil will be able to :

- instal the observation well into the soil;
- determine water table depth;
- interpret the fluctuations in water table during different seasons;

The teacher should evaluate the pupil for the above abilities.

12.4 Questions :

i. What is a water table?

ii. What is the importance of recording water table depths in agricultural lands?

iii. How does ground water table vary during the seasons?

iv. What are the harmful effects of high water table?

v. What is an observation well?

vi. What precautions will you take in installation of an observation well?

vii. The following are the moisture contents at different depths of soil profile above the water table which is at 155 cm from the ground surface :

Soil depth (cm)	*Moisture content (%) (Dry weight basis)*
0– 30	25
30– 60	22
60– 90	18
90–120	18
120–135	24
135–150	32

Comment on the data.

viii. How does the knowledge of water table depth help in the choice of crops to be grown?

13. Activity Unit

LAND DRAINAGE FOR CROP PRODUCTIVITY

13.1 Instructional objectives :

The pupil should be able to:

- recall the meaning of waterlogging:
- explain the adverse effect of waterlogging on soil, crop growth and yield;
- explain the factors causing excess water in soil;
- undertake the remedial measures to get rid of excess water;
- select the crops and varieties capable of withstanding waterlogged situations;
- recall the meaning of drainage coefficient and its approximate design value;
- calculate drainage coefficient on the basis of field observation.

13.2 Relevant information :

— What is waterlogging?

Presence of excess water in or near the root zone or standing water above the soil surface for any substantial period of time is known as waterlogging.

— Harmful effects of waterlogging

Presence of water in excess in a soil profile is considered harmful for the crop plants except those adapted to waterlogged situations (e.g. rice). The harmful effects of excess water are: i. limitation of aeration (oxygen) in the root zone, ii. accumulation of carbondioxide and toxic substances (H_2S, Ferrous sulphide, etc) in the root zone, iii. reduced water uptake, iv. reduced nutrient uptake resulting in nutritional deficiency symptoms, v. development of soil salinity and alkalinity, vi. anaerobic condition and prevalence of plant disease, and vii. stunted plant growth and reduction in yield.

—Causes of waterlogging

The problem of waterlogging is encountered chiefly due to the following:

i. Low infiltration rate as in heavy black cotton soils or soils having an impervious calcareous (Kankar) layer at shallow depth.
ii. Heavy showers over a short period of time or prolonged abnormal heavy rains.
iii. Flooding of the streams.
iv. Deep percolation and/or seepage from the storage reservoirs, canal distributories and water courses.
v. Over irrigation.
vi. Absence of drainage.

— What is drainage?

Removal of excess water from the field/crop root zone is termed as drainage.

— Methods of removal of excess water

Excess water can be removed by surface drainage, subsurface drainage or both.

i. SURFACE DRAINAGE :

In this method, the excess surface water is removed from the cropped area by a network of surface drains. A typical network of surface drains will consist of field drains, lateral drains and main drains. Field drains are shallow channels of about 15 cm depth and very flat side slopes. These are constructed at the time of land preparation for crops. Their main purpose is to provide a quick passage for the runoff water generated in the cropped land during rain fall. The spacing between these drains may vary between 100 to 200 metres. The slope of these drains should be 0.2% or more. But usually the slope will follow the general topography. In areas prone to surface waterlogging the land preparation should be such that atleast a 0.2% slope is provided in the direction of flow in the field drains. A number of such field drains join a lateral drain. A lateral drain is a drain of trapezoidal section having a minimum bottom width of

20 cm, stable side slope (1 : 1 or 1.5 : 1 are the usually adopted values) and depth varying from about 30 cm to a about 75 cm. The required section of the lateral drain is calculated by using Manning's formula, on the basis of drainage coefficient. is defined as the depth of water in mm, to be removed in 1 day (24 hours). This value varies from about 10 mm/day to about 40 mm/day. For lighter soil and low rainfall areas the surface drainage coefficient is low. For heavy soil and high rainfall areas the surface drainage coefficient is large. The excess water which is generated in the field and taken into the lateral drains, are to be disposed off into the main drains. A main drain may be a constructed drain or may be a natural stream.

ii. SUBSURFACE DRAINAGE :

In this method, the soil profile water is removed by underground perforated pipe drains or tile drains or by deep open drains. This is the most suitable method where the water table remains at shallow depth for most part of the year and when the ground water is saline. The subsurface drain depth may vary from 1 m to 2 m and spacing may be from 40 m to 80 m. Deeper the drains, the wider will be the drain spacing and vice versa. The drains may be of burnt clay tiles 30-60 cm long with or without perforation, asbestos pipe, slotted rigid PVC pipe or slotted flexible corrugated PVC pipe. The most common type of drains in the country are the burnt clay tile drains. The diameter of the drains may vary from 7.5 cm to 10 cm, depending on the discharge to be conveyed through them. The drainage coefficient for subsurface drainage is lower than that for surface drainage and seldom exceeds 10 mm/day. For laying the tile drains, first a trench is dug with desired longitudinal slope. A layer of filter material consisting of coarse sand, fine gravel, etc., of minimum 5 cm thickness is put. The drains are then laid with good alignment. A layer of filter is again put on the sides and on the top of the drains to a minimum thickness of 5 cm. The trench is then backfilled. The drains that remove the water from the field are called laterals. A number of laterals join a collector drain which is usually a closed pipe of larger (15 cm or more) diameter. These collectors then join the main drain, which is usually a deep open drain.

— Determination of drainage coefficient

Drainage coefficient can be estimated by using agro-climatological data, by using empirical relationships or from field data. The field data does not give the design value of drainage coefficient but gives its value as is obtained under, a given setup of drainage system and rainfall. This value may be modified to obtain the design drainage coefficient for similar areas. For determination of drainage coefficient from field observation, it is necessary to record the outflow from a watershed after a rainfall occurs. Since rain may occur at night, manual observation of flow is difficult therefore automatic water stage recorder is used for this purpose. Automatic water stage recorders are devices that measure and record the height of water flow (stage) over a calibrated structure (notch, weir, flume, etc.) continuously on a chart. Later, the chart is removed, and the stage values are converted to discharge using appropriate formula or table depending on the flow measuring device installed. The discharge is plotted with time and a curve is drawn through the plotted points. This curve is called a hydrograph (Fig. 13.2.1). The area under the graph represents the total volume of water that has flown during the time span of the curve. This volume divided by the area of the watershed gives the drainage coefficient.

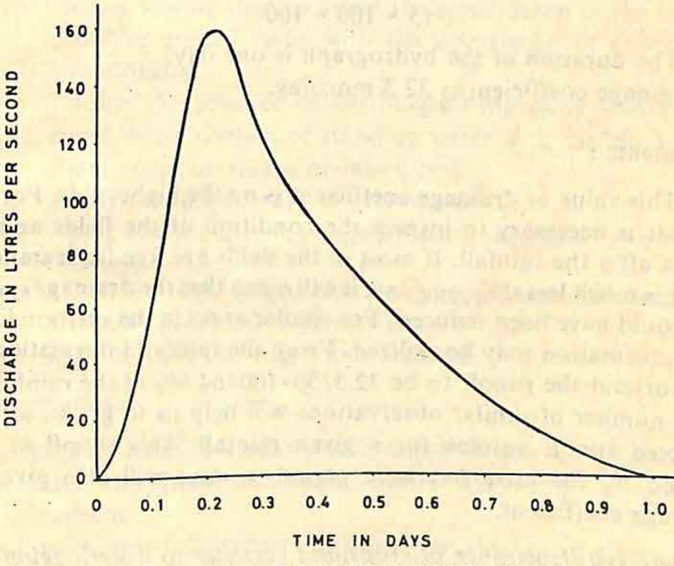

Fig. 13.2.1 HYDROGRAPH FOR CALCULATION OF DISCHARGE COEFFICIENT

Problem-1

At the outlet of a 15 ha subwatershed a calibrated flow measuring device and an automatic water stage recorder is installed. After a rainfall of 5 cm the stage recorder values were converted to discharge and the discharge and time are given below :

Time in days.	0	0.1	0.2	0.3	0.5	0.7	1
Discharge in lit/sec.	0	60	160	120	64	26	0

Calculate the drainage coefficient and comment on the result.

Solution

Plot the discharge and time data on a graph keeping time on the horizontal axis and discharge on the vertical axis.

Find the area under the curve by counting squares or by using a planimeter. For this problem, the area under the graph = 28 cm^2.

Now 1 cm^2 represents (20 lit/sec) × (0.1×24×3600 sec) litre of water = 172800 litres = 172.8 m^3 of water

$\therefore$ 28 cm^2 =4838.4 m^3 of water = 0.0323 m = 32.3

Since the watershed area is 15 ha the above volume of water can be expressed as :

$$\frac{4838.4}{15 \times 100 \times 100} = 0.0323 \text{ m} = 32.3 \text{ mm}$$

The duration of the hydrograph is one day.

$\therefore$ Drainage coefficient is 32.3 mm/day.

Comments :

This value or drainage coefficient is on the higher side. For this area, it is necessary to inspect the condition of the fields and the drains after the rainfall. If most of the fields are free from standing water is much less than one day, it will mean that the drainage system size could have been reduced. For similar areas in the surroundings, this information may be utilized. From the rainfall information we can workout the runoff to be 32.3/50×100=64.6% of the rainfall. A large number of similar observations will help us to get an idea of expected runoff volume for a given rainfall. This runoff in mm divided by the crop tolerance period in days will also give the drainage coefficient.

— *Sensitivity/tolerance of crops and varieties to waterlogging*

Crops and varieties differ considerably in respect of their sensitivity to excess water. In general, crops like surgarcane, grasses, small grain cereals are more tolerant to excess water than maize, cotton, legumes, oilseeds, vegetables, tuber crops and fruit trees. The latter group of crops suffers serious damages even if subjected to waterlogged condition for very short duration. Crops like chestnut, paddy and jute are suitable for waterlogged conditions.

—Crop stages sensitive to waterlogging

Usually germination stage is sensitive to waterlogging for all crops. Further, seedling stage for maize, red gram, bengal gram, etc., and flowering stage for chillies and tomato are more susceptible to waterlogging.

—Package of practices for cropping on land prone to waterlogging

i. Provide a good drainage system.
ii. Select water tolerant crops and varieties.
iii. Sow short duration varieties to escape the period of waterlogging.
iv. Adjust sowing time to avoid the coincidence of the most sensitive critical stage with the occurrence of expected waterlogging.
v. Follow the practice of earthing during rainy season to avoid direct contact of standing water with the plant.
vi. Plant crops on ridges or raised beds.
vii. Apply micro-nutrients, if necessary.
viii. Apply additional nutrient, particularly nitrogen, soon after flooding.
xi. Maintain high population to compensate the seedling mortality and loss of plant vigour.
x. Practise transplanting where feasible.

13.3 Precautions:

- Properly identify a subwatershed and its drainage channel.
- Select the flow measuring device according to outlet condition.
- Ensure proper installation of the flow measuring device.

13.4 Materials required :

i. Flow measuring device
ii. Automatic water stage recorder
iii. Rain gauge
iv. Spade

Alternatively, the discharge vs time and rainfall information of a subwatershed of known area.

13.5 Procedure:

- Instal the calibrated flow measuring device, the automatic water stage recorder at the outlet and the rain gauge in the middle of the watershed.
- After a rainfall when the drain flow has ceased, collect the stage recorder chart.
- Convert the stage values to discharge values and prepare a table of discharge and time as given in the solved problem. If discharge-time data are available make use of that.
- Find the rainfall depth from the rain gauge.
- Find the area of the subwatershed from the map.
- Plot the discharge-time data in the form of a hydrograph as given in the solved problem. Find the area of the hydrograph and express it in terms of volume of runoff.

13.6 Observations:

The pupil should record the following:

- Discharge-time data.
- Rainfall.

13.7 Calculations:

The pupil should calculate the following:

Area of the hydrograph = $cm^2 \equiv m^3$ of runoff (V)
Area of the subwatershed in ha = m^2 (A)
Equivalent depth of runoff = V/A m = $V/A \times 1000$ mm
Duration of hydrograph (T) = days
Drainage coefficient = $V \times 1000/A \times T$ mm/day

13.8 Expected behavioural outcomes:

The pupil will be able to:

- explain the meaning of waterlogging;
- recall harmful effects of waterlogging;
- recall about package of practices for areas prone to waterlogging;
- explain the methods of drainage;

Grade

— explain drainage coefficient;
— calculate drainage coefficient from field observation.

The teacher should evaluate the pupil for the above abilities.

13.9 Questions:

i. What is meant by the term 'waterlogging?
ii. What is drainage?
iii. What is meant by drainage coefficient?
iv. Name three crops which are considered tolerant to excess water conditions.
v. Name two crops which are considered very sensitive to excess water.
vi. Drainage problem is more severe in......................soils than in............................soils.
vii. Silty loam soils in general would have better drainage than loamy lands. True/False
viii. High water table leads to the problem of soil salinity. True/False
ix. Under what situation surface or sub-surface drainage is used?
x. What are the causes of waterlogging?

14. Activity Unit

MANAGEMENT OF RAIN WATER

14.1 Instructional objectives :

The pupil should be able to:

- explain management of rain water;
- make the best use of rain water and land resource;
- recall various practices for good management of rain water on slopy and flat lands;
- recall how excessive run-off can be made use of;
- measure run-off from a small plot;
- measure sediment load from a cropped and fallow small plot.

14.2 Relevant information

— *What is rain water management?*

Rain water is a boon to agriculture but if it is not managed properly, it can prove to be a curse. It can cause an irreparable damage to land by forming rills, gullies and ravines. Good management of rain-water means that its largest fraction is retained by the soil and the excess leaves the field without causing any damage to soil/land.

— *Why catchment as the basis?*

The rain water has to be managed where it falls and has to be followed along its flow. That is, water has to be managed starting at the ridge downwards. Thus, catchment becomes the logical unit for the management of run-off.

— *Why do problems vary according to land slope and soil type?*

The problems caused by run-off water vary according to the soil type and slope of land. On slopy lands having slope more than 1 per cent, it causes erosion by forming rills, gullies and ravines and the problem is aggravated by deepening of gullies (due to bad erosion) and their broadening every year (on fall of banks) by run-off water, and by formation of side gullies and ravines, thus leading to colossal loss of cultivable lands every year. On flat lands the rain water causes problems of water-stagnation, water-logging, etc., which are more serious on soils of clay texture and less so on sandy, sandy loam, and loam soils.

— *Management practices for slopy lands*

On slopy land (slope 1 to 6%), the most prominent problem is the soil erosion caused by run-off water in the cultivated fields. To check this, construction of following structures and creation of good plant cover are necessary:

i. WATER DIVERSION BUNDS:

To divert water coming from upper reaches into cultivated fields, if any.

ii. GRASSED WATER–WAYS :

To take away water from fields, diverted by water diversion bunds, contour bunds, graded bunds, etc.

iii. CONTOUR/GRADED BUNDS :

To divide the whole catchment into parts so that run-off water does not gain velocity while running on slope. Construction of contour bunds on light soils and graded bunds on heavy soils is recommended (Fig. 14.2.1)

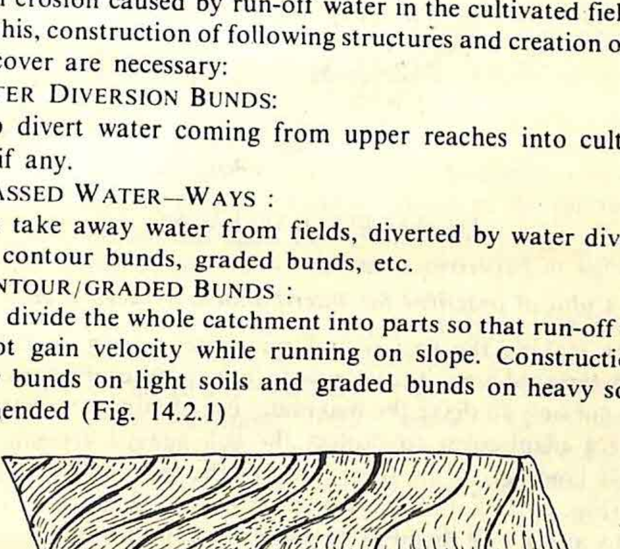

Fig. 14.2.1 GRADED BUNDS

iv. RIDGES AND FURROWS :

Ridges and furrows are made to allow better retention and storage of moisture during drought.

v. TIE-RIDGES :

This is dividing the furrows by making small obstructions in the furrow at every 5 m interval or so. This leads to more efficient utilisation of any sudden shower which may create large runoff through the furrow.

On lands with slope of 6% and above, bench terracing has to be done to manage the rainwater (Fig. 14.2.2).

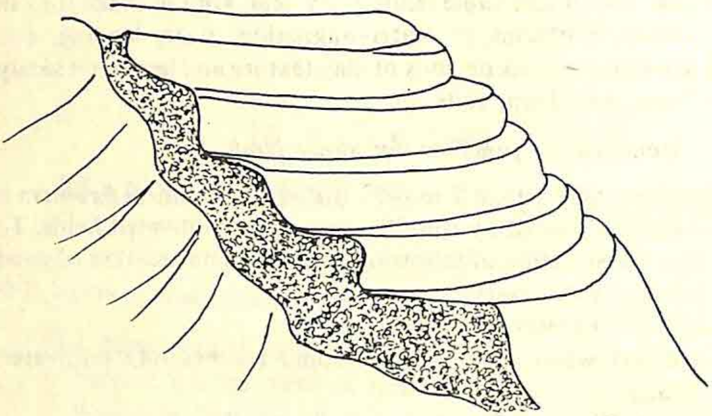

Fig. 14.2.2 BENCH TERRACING

— *Cultural practices for inter-bunded/terraced area*

For making the best use of rain-water falling on the inter-bunded/terraced area, it is necessary; (a) to grow crops during rainy season not only to make the maximum use of rain-water but also to provide a plant-cover to protect the soil against erosion; (b) to cultivate land across the slope to allow the maximum retention of water (Fig. 14.2.3); and (c) to plant crop on a grade (0.3 to 0.5 per cent) to allow safe disposal of excessive runoff.

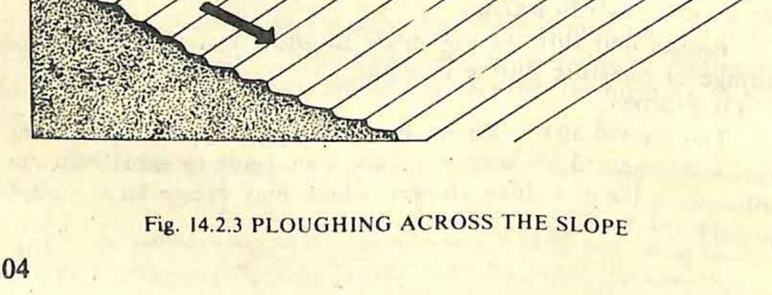

Fig. 14.2.3 PLOUGHING ACROSS THE SLOPE

On light soils showing a tendency of crust-formation, stirring the upper layer of the soil with small tyned harrow helps in infiltration of rain water and conservation of moisture.

— *Management practices for flat lands*

On flat lands (with less than 1% slope), particularly those having deep black clay soil, the rain-water causes only sheet erosion-washing away of soil particles, and does not move in or move away at a sufficient rate. Consequently, problems of water-logging (high water table-real or perched) and/or surface water stagnation are caused. To overcome these problems, construction of surface channels (graded furrows) leading water into graded channels discharging into grassed water-ways is necessary.

— *Run-off collection and recycling*

— RUN-OFF COLLECTION : The excessive run-off water can be collected suitably in any of the following ways depending upon the specific site:

(a) *Tank* : Tanks can be constructed at suitable sites with provision for spill way.

(b) *Farm ponds* : Taking advantage of the natural topography of the catchment, the lowest fields can be used for surface storage of the excessive run-off.

(c) *Check dams across 'nalas'* : Check dams with flexible or fixed levels across the 'nalas' can be constructed to store run-off water.

— RECYCLING OF COLLECTED RUN-OFF :

The collected run-off water can be used for irrigation as follows:

(a) to give life saving irrigation to rain fed crops at their critical stages in case of prolonged dry spell, and

(b) to give irrigation for germination of next season crops and supplementary irrigation at their critical stages if, water is still available.

14a. Sub Unit: **Measurement of Runoff by Drum Technique**

14a.1 Precautions :

- See that the bunds are strong enough not to allow rain water from outside the plot to flow into the drum.
- Protect bunds and the slit against erosion by covering them with polyethylene sheets.
- See that the edge of the drum is in level with field surface.

14a.2 Materials required :

i. *A small plot (4 m × 1 m)
ii. Drum (200 litres capacity)
iii. Metre scale
iv. Spade
v. Pick axe.

14a.3 Procedure :

- Select a small plot (4 m × 1 m) such that the length is along land slope of 2-3 per cent.
- Construct and compact the bunds (15 to 20 cm high) around the plot (on all the four sides).
- Smoothen the soil surface in plots maintaining the desired slope.
- Dig a pit with the help of a spade and pick axe, just outside the plot towards the slope. The pit should be large enough to accommodate the drum.
- Fix the drum in the pit, pack the soil around the drum.
- Make a slit in the appropriate bund where the edge of drum touches it to let in run-off water from the plot into the drum.

14a.4 Observations :

The pupil should record the observations as per the table given on the next page.

---

* Standard size of runoff plot is 20 m × 5 m

Date	*Amount of rainfall received (cm)*	*Depth of water collected in the drum (cm)*	*Remarks*

14a.5 Calculations :

The pupil should calculate the runoff as per illustrations given below :

Suppose :

i) Depth of water = 20 cm
ii) Diameter of the drum = 70 cm
iii) Volume of water $= \pi r^2 h \times 1/1000$
$= 22/7 \times 35/1 \times 35/1 \times 20/1000$
= 77 litres

If there was 5 cm rainfall the volume of rain fall = Area of the plot (in cm^2) × Rainfall in cm / 1000
$= 400 \times 100 \times 5/1000 = 200$ litres

Run-off $= 77 \times 100/200 = 37.5\%$

14b. Sub Unit: Measurement of the Sediment Load of Runoff Water from Cropped and Bare Plot

14b.1 Precaution :

— Stir thoroughly the collected runoff water before sampling.

14b.2. Materials required :

i. Two (4 m × 1 m) plots—one cropped and the other fallow.
ii. Drums
iii. Porcelain dishes
iv. Analytical balance
v. Weight box
vi. Glass cylinder
vii. Pipette (100 ml)
viii. Hot plate/water bath

ix. Spade
x. Pick axe

14b.3 Procedure :

- Instal one drum outside the cropped plot and another outside the fallow plot.
- Follow procedure given in the Sub Unit 14a for installation of the drums.
- Collect runoff in the drums from each plot separately.
- Collect the sample from each drum in a glass cylinder after stirring the contents thoroughly.
- Again stir the contents of the cylinders and take sub-samples of 100 ml with 100 ml pipette in two pre-weighed porcelain dishes.
- Evaporate the contents of both the dishes on a hot plate/water bath.
- Cool and weigh the porcelain dishes with their content.

14b.4 Observations :

The pupil should record the observations as per the table given below :

Cropped plot 'A'	*Bare (Fallow) plot 'B'*
Wt. of empty dish = X g	Wt. of empty dish = X_1 g
Wt. of dish with sediment = Y g	Wt. of dish with sediment = Y_1 g
Wt. of sediment = (Y–X) g	Wt. of sediment = (Y_1-X_1) g

14b.5. Calculations :

The pupil should calculate the sediment loss of runoff water for cropped and bare plots separately.

For cropped plot 'A'

Wt. of sediment = Y–X g
Wt. of sediment in run-off water = 77000×(Y–X)/100 g
using the value from 14a.7
(77 litre = 77000 cm^3) = 770 × (Y–X) g
Soil loss from 4 m^2 land = 770×(Y–X) g
Soil loss from 1 ha land = $770\times(Y-X)\times100\times100/4\times100\times1000$ q
= 77/4 × (Y–X) q/ha

For bare plot 'B'

Wt. of sediment $= (Y_1 - X_1)$ g
Wt. of sediment in run-off water
using the value from 14a.7 $= 770 \times (Y_1 - X_1)$ g
(77 litre = 77000 cm^3)
Soil loss from 4 m^2 land $= 770 \times (Y_1 - X_1)$ g
Soil loss from 1 ha land $= 77/4 \times (Y_1 - X_1)$ q/ha

14.3 Expected behavioural outcomes:

The pupil will be able to :

- identify water erosion/soil loss problems and their extent;
- suggest measures for good management of rain-water on slopy lands;
- suggest measures for good management of rain water on flat lands with heavy and light texture soils;
- assess the effect of crop cover on soil loss;
- measure runoff and sediment loss.

Grade

The teacher should evaluate the pupil for the above abilities.

14.4 Questions :

i. Strike out the wrong word :
   a) Soil loss is higher/lower in a slopy field as compared to level field.
   b) Runoff is less/more in clayey soil as compared to sandy soil.
   c) Runoff will be higher/lower in a slopy field as compared to levelled field.
   d) The rate of infiltration in a soil is higher/lower in cropped field as compared to bare field.
   e) Cultivation against slope increases/reduces retention of rain water.
   f) The soil loss is high/low under groundnut crop as compared to cotton crop.

ii. From a field 100 m long and 40 m broad, 2000 litres of runoff water was collected at the end of a rainfall. If the rainfall measured is 5 cm, calculate the percentage of runoff.

iii. From a field 20 m × 5 m, the soil loss recorded was 30 kg at the end of rain, calculate soil loss in tonnes/ha.

15. Activity Unit

CONSERVATION OF SOIL MOISTURE BY STRAW MULCHING

15.1 Instructional objectives :

The pupil should be able to :

- explain how to increase profile stored moisture;
- explain how to conserve the profile stored moisture;
- explain how to get maximum return per unit of stored moisture;
- explain how to increase moisture use efficiency;
- measure the effect of mulches.

15.2 Relevant information :

— *Importance of profile stored moisture*

The profile stored soil moisture becomes important to raise a good crop in areas where rainfall is scarce, intervals between rains are sufficiency large and irrigation facilities do not exist. Therefore, an attempt has to be made during the wet spells to increase the amount of soil profile moisture.

— *How to increase profile stored moisture?*

In coarse textured soils (sandy and sandy loam), the water infiltrates easily into the soil profile and the profile easily gets charged with water. In black clay soils having expanding type of clay mineral as the dominant one, the soil surface gets almost sealed after it gets wet and thus, the infiltration rate is reduced considerably. The moisture storage in black soils can be increased by :

i. making ridges and furrows on the field surface/against the slope;

ii. applications of organic mulches and organic matter to the soil before rains start; and

iii. application of vertical mulch by making a vertical trench on the field surface and filling it with any type of organic material e.g. sorghum stubbles.

In some soils, formation of hard pan takes place below the soil surface. Deep ploughing to break this hard layer increases the storage of moisture in such soils.

— *How to conserve the profile stored moisture?*

It is necessary to give a shallow cultivation as soon as the rainfall ceases and the soil comes to condition to create a thin layer of loose soil creating dust mulch. Other measures include use of stubbles, straw and plastics as mulch materials. Besides conserving moisture they also influence soil temperature.

— *How to make the best use of rain water and land resources*

To make the best use of land and water resources under dry farming conditions, the land has to be cropped during the season in which major rainfall is received. Raising a crop in this season will not only make the maximum use of rain water but will also provide a crop cover against erosion caused by rain water, particularly on slopy lands. It is desirable that the land is used according to its capability, considering the slope of land, depth and texture of the soil etc., as shown in table 15.2.1.

Table 15.2.1 : Suggested land use according to capability

Land type	*Suggested use*
— Bare hill slopes, steep land with shallow soil	Planting trees for fuel, fodder, fruits and grassess with legumes.
— Moderately slopy land with medium deep soil	Growing short duration kharif crops and their improved/hybrid varieties e.g. hybrid sorghum for grain, fodder, sorghum soybean, etc.
— Flat lands with deep soil :	
i. Sandy, loam, sandy loam soils	Growing sorghum + pigeon pea, pearlmillet/maize + pigeon pea
ii. Black clay soil	Sorghum + pigeon pea, Soybean + pigeon pea, or Sorghum-gram/safflower sequence

The strategy in dry farming is to make the best use of rain water while it falls and also the exploitation of profile stored moisture. The profile stored moisture can be best exploited by :

i. growing deep rooted crops such as castor, pigeon pea, cotton, gram and safflower on heavy soils, and mustard and *Eruca sativa* on light soils.
ii. adopting intercropping systems replacing sole crops say, of sorghum, soybean and cotton by sorghum + pigeon pea, soybean + pigeon pea and soybean + cotton so that advantage of residual moisture is taken by deep rooted long duration crops of pigeon pea and cotton.
iii. growing high yielding varieties of crops.

— *How to increase profile moisture use efficiency ?*

The efficiency of moisture use can be increased by adoption of improved practices of farming such as selection of appropriate crops and varieties, judicious use of fertilizers, adoption of weed control and plant protection measures, reduction of surface evaporation by mulching.

15.3 Precautions :

— Avoid mixing of mulch materials with soil while sampling for moisture determinations.

— Ensure uniform spread of straw mulch.

15.4 Materials required :

i. Two plots each of 2 m × 2 m
ii. Straw
iii. Auger
iv. Moisture boxes (Aluminium boxes)
v. Physical balance for determining soil moisture content
vi. Drying oven
vii. Measuring tape

15.5 Procedure :

— Select two well levelled plots of 2 m × 2 m sizes. Place a layer of straw weighing 6-8 t/ha on dry weight basis at the surface in one plot. Leave the other plot bare.

— Draw soil samples for determination of moisture content to a depth of 30 cm after every fifteen days from the bare and straw mulched plots separately.

— Determine their soil moisture content.

15.6 Observations :

The pupil should take the following observations :

i. Moisture content in bare plot :
Weight of moist soil + aluminium box = X g
Weight of oven dry soil + aluminium box = Y g
Weight of aluminium box = Z g

ii. Moisture content in mulched plot :
Weight of moist soil + aluminium box = X_1 g
Weight of oven dry soil + aluminium box=Y_1 g
Weight of aluminium box = Z_1 g

Moisture content under mulched and control plot :

Sample number	*Date of sampling (days after mulching)*	*Moisture (%) in mulched plot*	*Moisture (%) in control plot*	*Difference (%)*	*Difference in cm of water depth*
1.	15				
2.	30				
3.	45				

15.7 Calculations :

The pupil should calculate the moisture content in bare and mulched plots.

i. Moisture content in bare plot = $X-Y/ Y-Z \times 100\%$
ii. Moisture content in mulched plot = $X_1-Y_1/ Y_1-Z_1 \times 100\%$

15.8 Expected behavioural outcomes :

The pupil will be able to :

Grade

- increase the efficiency of the stored and conserved moisture;
- measure the effectiveness of straw mulch.

The teacher should evaluate the pupil for the above abilities.

15.9 Questions :

ii. Answer in 'YES' or 'NO'

a) Short duration crop like sorghum is better suited to dry farming than cotton. ( )

b) Hybrid varieties of sorghum perform better than desi varieties. ( )

c) Wheat exploits soil moisture better than safflower ( )

d) Growing a second crop of rice (in rabi) is better than growing safflower ( )

e) Sorghum intercropped with pigeon pea is less remunerative than sorghum alone, on deep black clay soils ( )

f) It is harmful to apply fertilizer to rainfed crops ( )

g) Application of FYM and compost is more useful under irrigated conditions than that under dry farming conditions. ( )

h) If one or two irrigations are available from the collected runoff water, two good crops in an year can be raised on medium and deep soils. ( )

i) Straw mulch increases yields of wheat. ( )

ii. Moisture content in bare soil (0-60 cm) is 15% and in mulched soil (0-60 cm) 20%. Calculate the quantity of water (cm) conserved by mulch, assuming soil bulk density to be 1.5 g/cm^{-3}

Appendix-I

PRACTICAL INTERPRETATION CHART OF SOIL MOISUTRE FOR VARIOUS SOIL TEXTURES AND CONDITIONS

Available	*Feel or appearance of soil*			
Moisture in soil	*Coarse-textured soil*	*Moderately coarse textured soils*	*Medium textured soils*	*Fine and very fine textured soils*
65 per cent to field capacity	Sticks together slightly may form a very weak ball under pressure	Forms weak ball that breaks easily does not stick	Forms ball very pliable; sticks readily if relatively high in clay	Ribbons out between fingers easily; has a slick feeling
At field capacity (100 per cent)	On squeezing, no free water appears on soil but wet outline of ball is left on hand	Same as for coarse textured soils at field capacity	Same as for coarse textured soils at field capacity	Same as for coarse textured soils at field capacity
Above field capacity	Free water appears when soil is bounded in hand	Free water is released with kneading	Free water can be squeezed out	Puddles; free water forms on surface
0 per cent	Dry, loose and single grained; flows through fingers	Dry and loose, flows through fingers	Powdery dry; in some places slightly crusted but breaks down easily into powder.	Hard, baked, and cracked, has loose crumbs on surface in some places
50 per cent or less	Appears to be dry; does not form a ball under pressure	Appears to be dry; does not form a ball under pressure	Somewhat crumbly but holds together under pressure	Somewhat pliable balls under pressure

50 to 75 per cent	Appears to be dry; does not form a ball under pressure	Balls under pressure but seldom' holds together	Forms a ball under pressure, somewhat plastic slicks slightly under pressure	Forms a ball, Ribbons out between thumb and forefinger

SOURCE (Hand Book on irrigation water management, Water Management Division, Ministry of Agri., New Delhi, Technical series-3, 1971).

Appendix II

DEFINITION OF SOME IMPORTANT TERMS USED IN THE MANUAL

Available soil moisture is the amount of moisture which is held between field capacity and permanent wilting point of a soil.

Bulk Density or Volume Weight is the ratio of weight of oven dry soil to its bulk maximum volume.

Capillary water is that water which is held by surface tension forces as a continuous film around the soil particles against the pull of gravity.

Consumptive Use (CU) is the quantity of water lost in evaporation, transpiration and that used by plants in metabolic activities from a particular area during a specified time. It is expressed as depth of water in millimetres with respect to time.

Contour is the loci of equal elevations or the imaginary line joining the points of equal elevation.

Critical Stage is the period during which yield of a crop is affected severely due either to inadequate or excess moisture.

Drainage is the removal of excess water from the soil surface and/or from soil profile by artificial means to enhance crop production.

Drainage Coefficient is the amount of water to be removed by drainage for optimum crop production. It is expressed in mm/day.

Electrical conductivity is the property of a medium of transferring electric charge. It is the reciprocal of electrical resistance and is expressed in reciprocal of Ohm/cm as mho/cm.

Evapotranspiration (ET) is the total water lost due to evaporation from soil and transpiration from crop for a particular area during a specified time. It is generally expressed as depth of water in millimetres with respect to time. It is practically equal to consumptive water use by a crop.

Field capacity is the moisture percentage of a soil on oven dry basis when the soil has been completely saturated and downward movement of excess water has practically ceased.

Fifteen bar percentage is the moisture percentage of a soil sample which has been wetted and brought to an equilibrium in a pressure membrane apparatus at 15 bar pressure. This moisture value approximates the lower limit of available water i.e., permanent wilting point.

Ground water table : Upper surface of ground water which is at atmospheric pressure.

Irrigation application efficiency is the ratio, expressed in percentage, of water stored in the root zone depth of soil to water delivered to the field.

Irrigation requirement refers to the depth of water required to be applied for successful growth of crops, in a given time, exclusive of rainfall, ground water contribution and other natural resources. This, in other words, can be stated as net irrigation requirement plus other economically unavoidable losses.

Leaching requirement is the fraction of the water entering the soil that must pass the root zone in order to prevent soil salinity from exceeding a specified value.

Potential evapotranspiration (PET) is the amount of water evaporated in a unit time from a short uniform green crop, growing actively and covering an extended surface and never short of water.

Water need or water requirement (WR) is defined as the depth of water needed for raising a crop in a given period. It includes consumptive use and other economically unavoidable losses and that applied for special operations such as land preparation, transplanting, leaching, etc.

Water shed is the area above the given point on a stream that contributes water to the flow at that point. Catchment, basin or drainage basin are synonymous with it.

Appendix—III

CONVERSION TABLE

One hectare centimetre = 100 cubic metre
One acre inch = 3630 cubic feet or 102 cubic metres (Approx.)
One cusec for one hour = 3600 cubic ft. or approx. one acre inch.
One hectare = 10,000 square metres
One acre = 4,840 sq. yards = 43560 sq. ft = 0.405 ha
1 sq. km. = 100 hectares
1 sq. mile = 640 acres = 2.59 sq. km.
1 cm depth water per sq. metre area = 10 litres
1 cubic ft = 6.24 gallons (one gallon = 4.546 litres)
Kilo litre = 1000 litres

Irrigation water : Electrical conductivity of water is related to salt concentration as follows :

1. Total soluble salts ppm = EC $\times 10^{-6} \times 0.64$
2. Per cent salts in water = ppm $\times 10^{-4}$
3 me/litre = EC $\times 10^{3} \times 10$ (approx.)

Weights, volumes and measurements of common use :

One hectare = 2.47 acres (1 acre = 0.404686/ha)
One inch = 2.54 cm (1 cm = 0.394 inch)
One yard = 0.91 metre (1 m = 1.094 yards)
One pound = 0.4536 kg (1 kg = 2.20 lb)
One tonne = 1000 kg or 10 quintals
Pounds per acre = 1.121 kg/ha (0.892 lb/acre = 1 kg/ha)
Pounds per acre = 0.011 g/ha (q/ha = 89.271 lb/ha).
Gallons/acre = 11.21 lt/ha or 1 lt/ha = 0.089 gal/acre

Appendix-IV

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Crop
Depth of water required prior to irrigation
Depth of w… during irri…
HEAD DITCH
E_a=100% E_s=80% E_d=80%
(a)
E_a=80% E_s=90% E_d=85%
(b)
E_a=60% E_s=100% E_d=90%
(c)
E_a=100% E_s=60% E_d=70%
(d)
E_a=85% E_s=80% E_d=75%
(e)
E_a=75% E_s=100% E_d=80%
(f)
E_a=100% E_s=50% E_d=75%
(g)
E_a=90% E_s=90% E_d=85%
(h)
E_a=60% E_s=100% E_d=95%
(i)

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